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Jonsson et al.

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(54) **METHODS OF SELECTING MIMO RANKS AND RELATED DEVICES**

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§ 371 (c)(1),
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PCT Pub. Date: **Oct. 3, 2013**

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(51) **Int. Cl.**
H04B 7/04 (2006.01)
H04L 1/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04B 7/0486*** (2013.01); ***H04L 1/0026*** (2013.01); ***H04L 1/0618*** (2013.01); ***H04L 1/1671*** (2013.01); ***H04L 1/1867*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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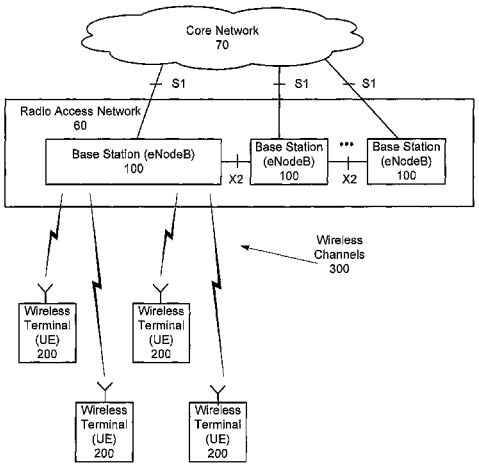
Assistant Examiner — Hong Shao
(74) *Attorney, Agent, or Firm* — Myers Bigel & Sibley, P.A.

(57) **ABSTRACT**

A method of operating a wireless network node may include transmitting a first MIMO downlink communication to a wireless terminal according to a first MIMO rank, and receiving at least one HARQ ACK/NACK, message from the wireless terminal corresponding to the first MIMO downlink communication. A report may be received from the wireless terminal identifying a reported MIMO rank, and a second MIMO rank may be selected for a second MIMO downlink communication responsive to the at least one HARQ ACK/NACK message. The second MIMO downlink communication may be transmitted to the wireless terminal according to the second MIMO rank.

26 Claims, 20 Drawing Sheets



(51) **Int. Cl.**

H04L 1/06	(2006.01)
H04L 1/16	(2006.01)
H04L 1/18	(2006.01)

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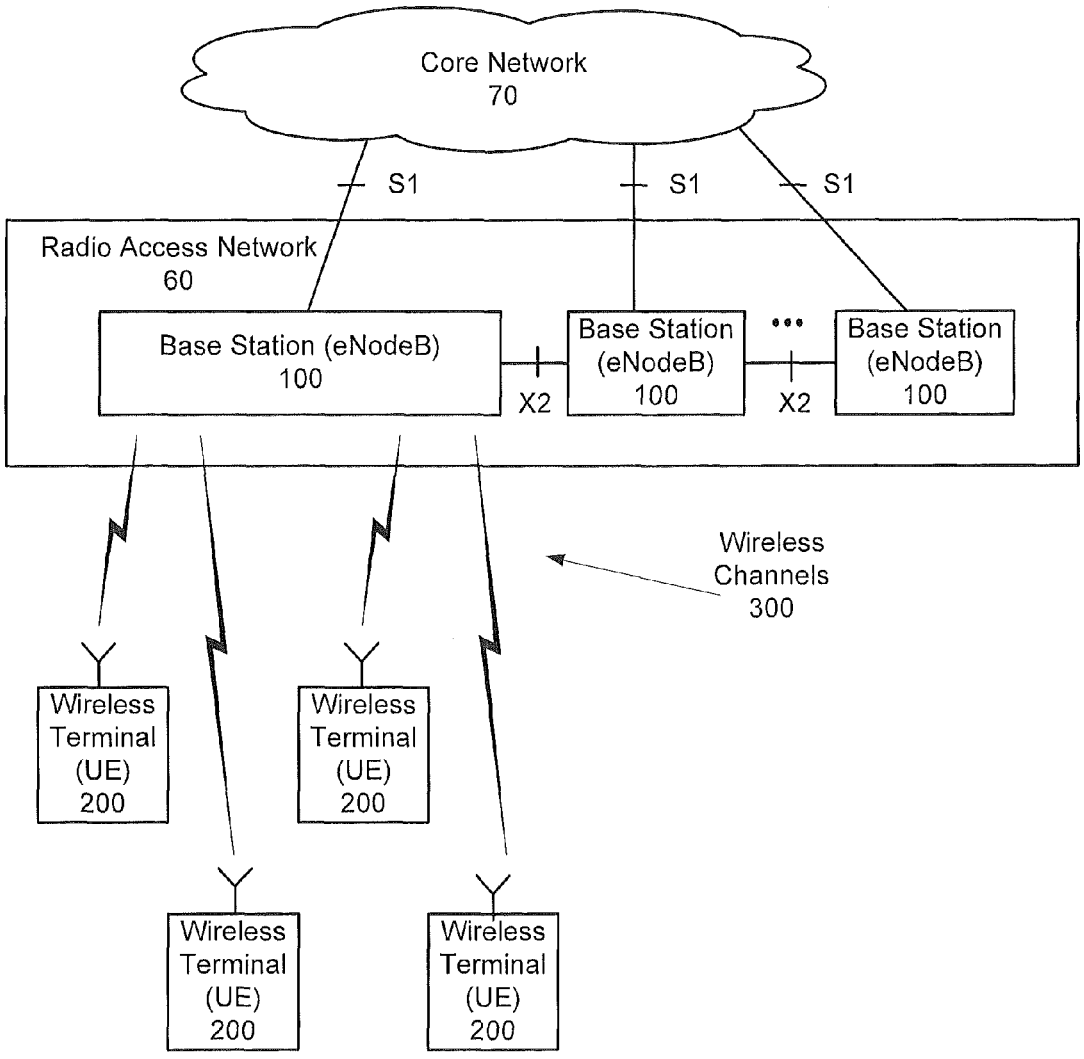
Figure 1


Core Network
70
S1
S1
S1
Radio Access Network
60
Base Station (eNodeB)
100
X2
Base Station
(eNodeB)
100
X2
Base Station
(eNodeB)
100
Wireless
Channels
300
Wireless
Terminal
(UE)
200
Wireless
Terminal
(UE)
200
Wireless
Terminal
(UE)
200
Wireless
Terminal
(UE)
200

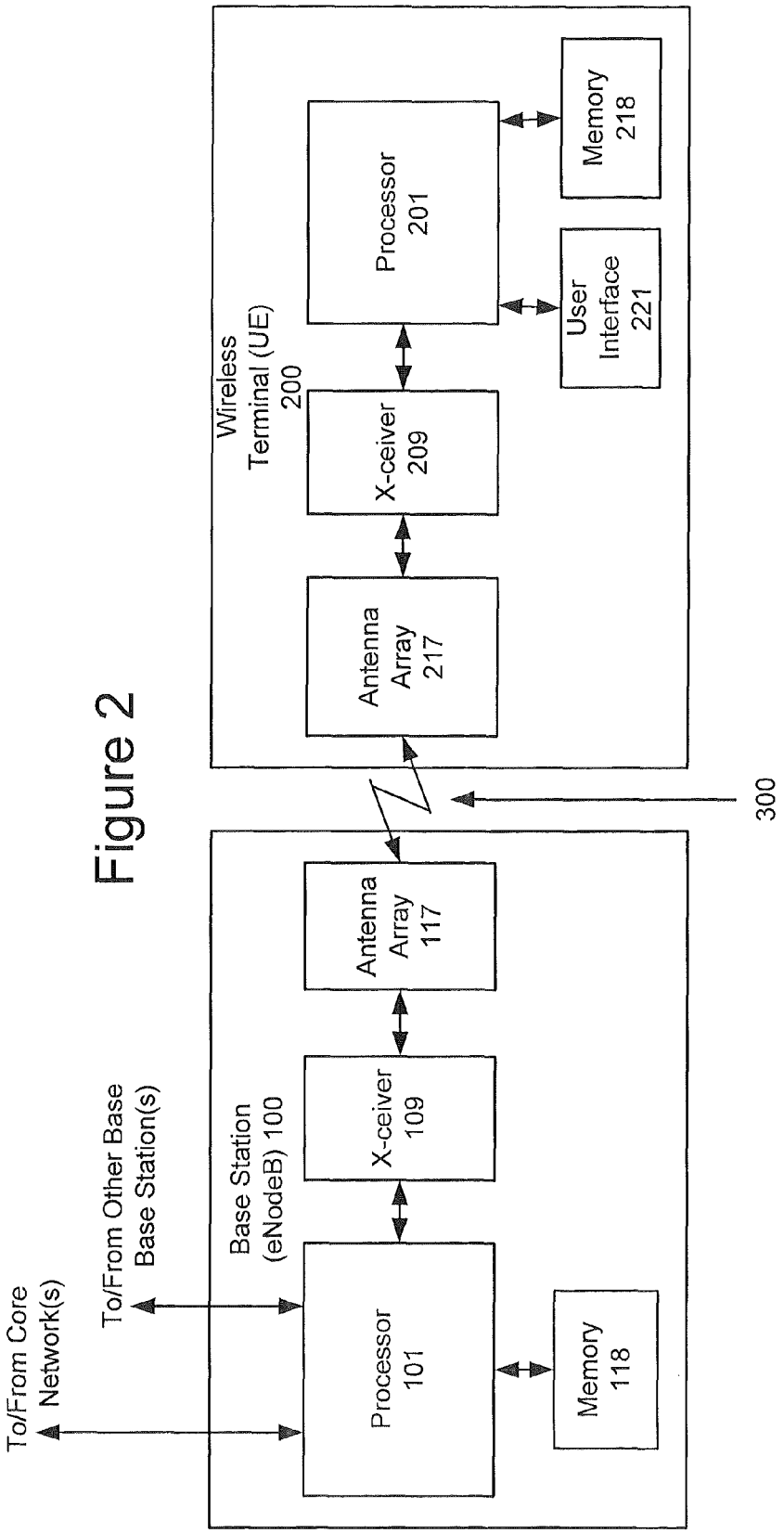

To/From Core Network(s)
To/From Other Base Base Station(s)
Base Station (eNodeB) 100
Processor 101
Memory 118
X-ceiver 109
Antenna Array 117
300
Wireless Terminal (UE) 200
Antenna Array 217
X-ceiver 209
Processor 201
User Interface 221
Memory 218

Figure 2

Figure 3A

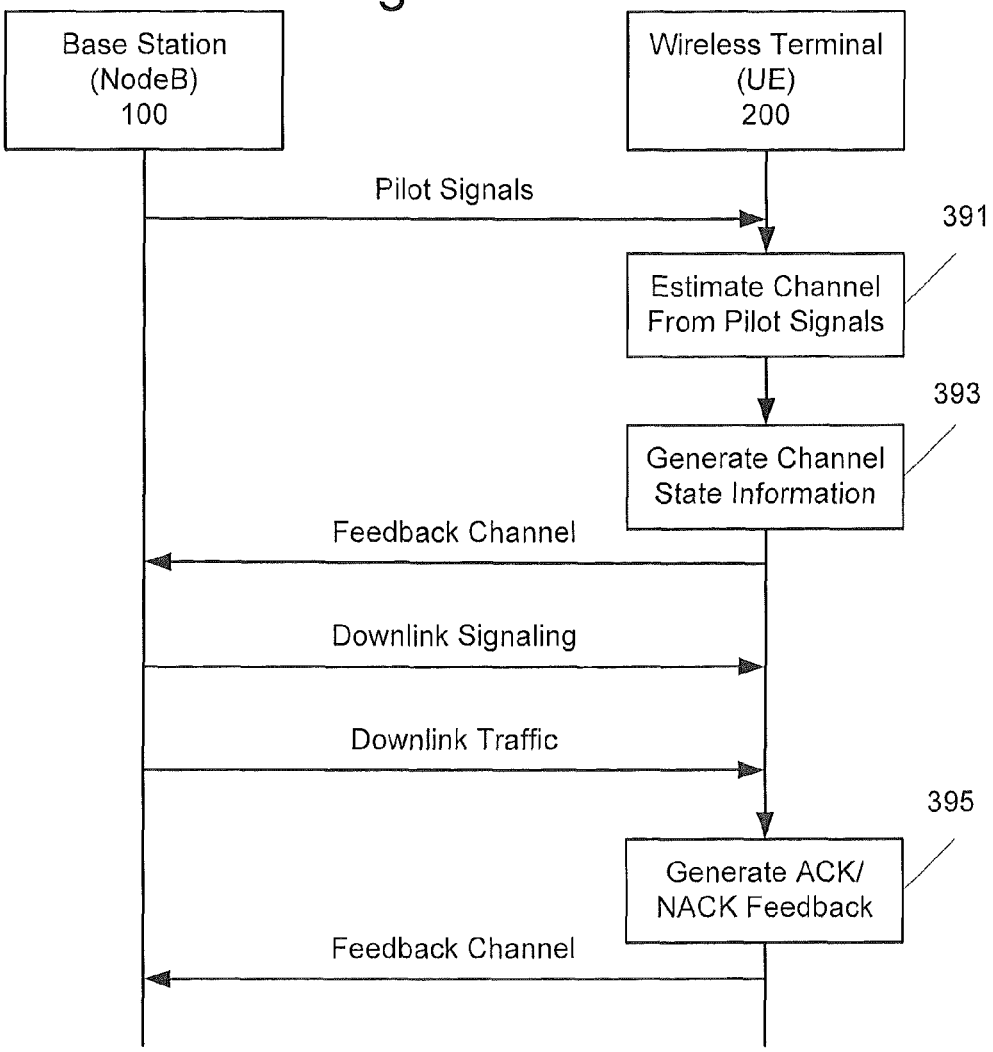


Figure 3B

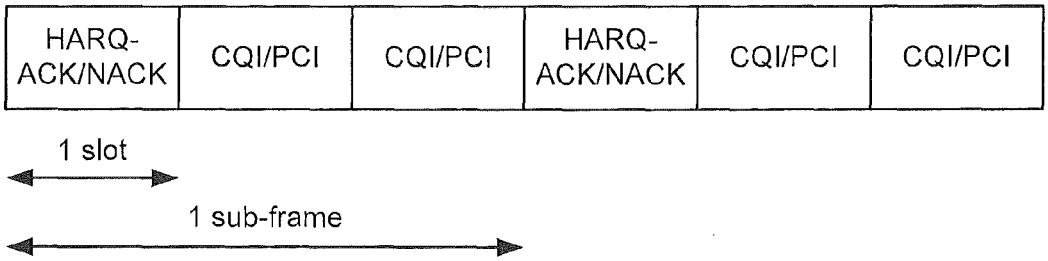


Figure 4

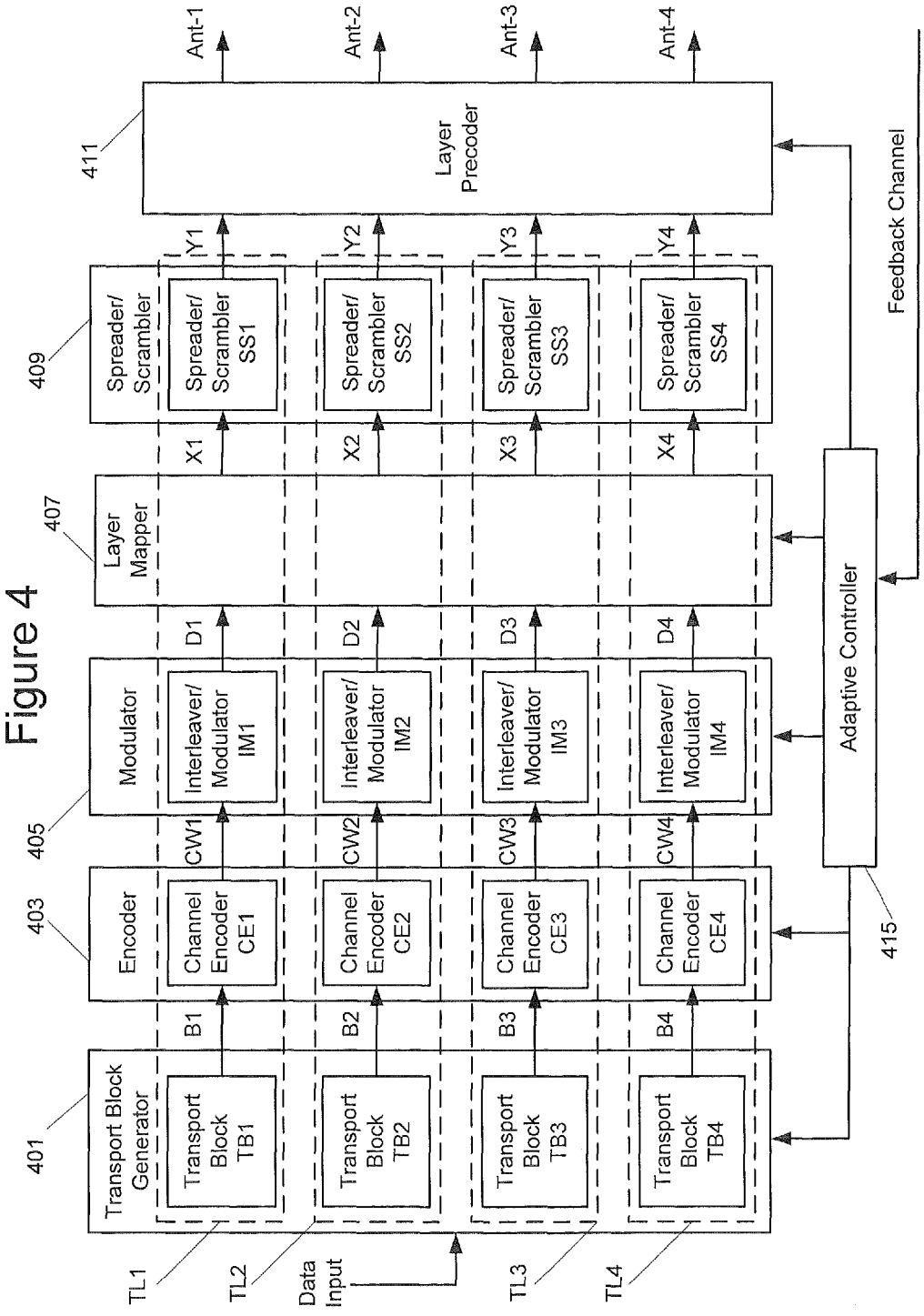

401
Transport Block Generator
Transport Block TB1
Transport Block TB2
Transport Block TB3
Transport Block TB4
403
Encoder
Channel Encoder CE1
Channel Encoder CE2
Channel Encoder CE3
Channel Encoder CE4
405
Modulator
Interleaver/ Modulator IM1
Interleaver/ Modulator IM2
Interleaver/ Modulator IM3
Interleaver/ Modulator IM4
407
Layer Mapper
409
Spreader/ Scrambler
Spreader/ Scrambler SS1
Spreader/ Scrambler SS2
Spreader/ Scrambler SS3
Spreader/ Scrambler SS4
411
Layer Precoder
B1
B2
B3
B4
CW1
CW2
CW3
CW4
D1
D2
D3
D4
X1
X2
X3
X4
Y1
Y2
Y3
Y4
Ant-1
Ant-2
Ant-3
Ant-4
TL1
TL2
TL3
TL4
Data Input
Adaptive Controller
415
Feedback Channel

Figure 5

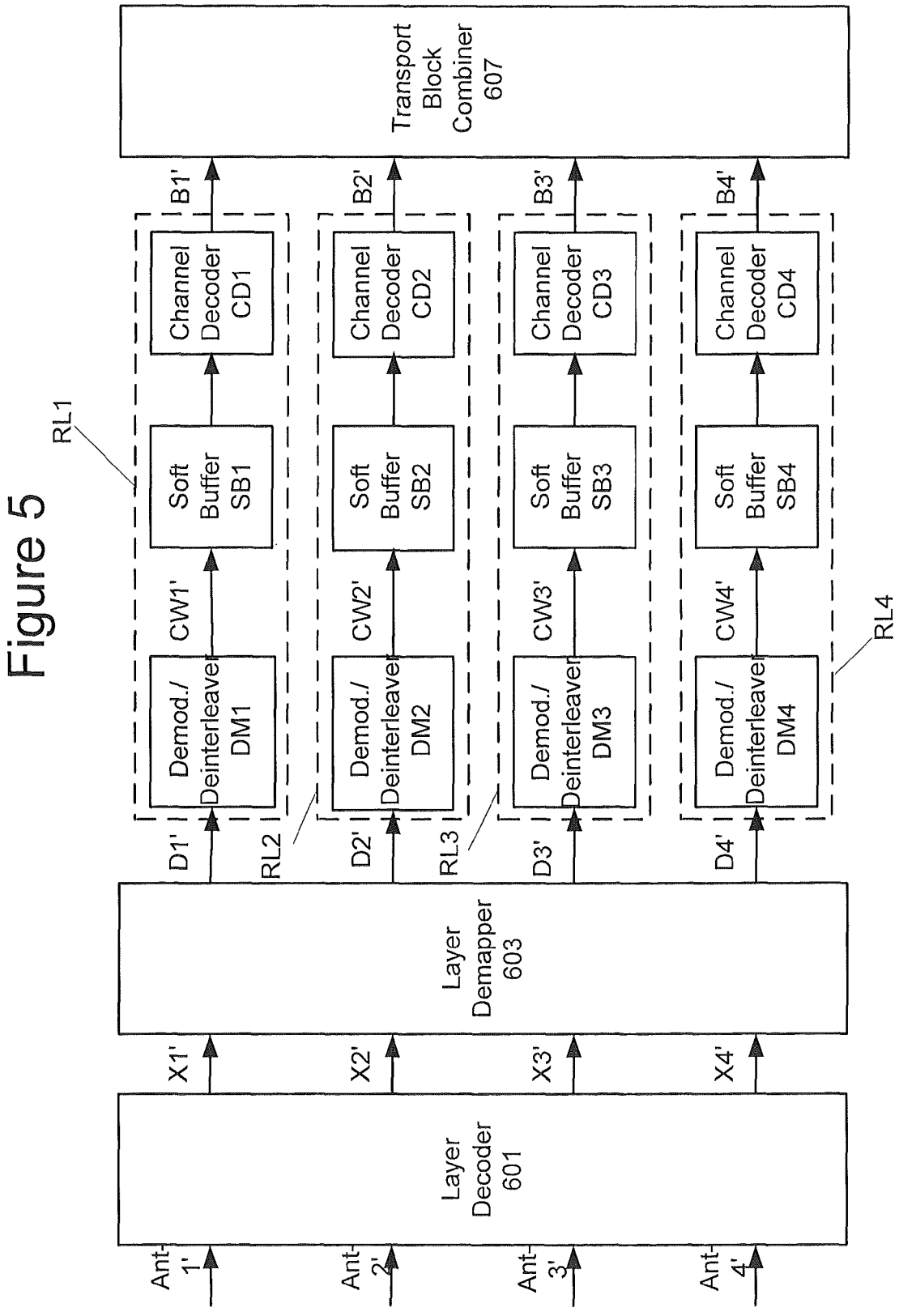

Ant 1'
Ant 2'
Ant 3'
Ant 4'
Layer Decoder 601
X1'
X2'
X3'
X4'
Layer Demapper 603
D1'
D2'
D3'
D4'
RL1
RL2
RL3
RL4
Demod./ Deinterleaver DM1
Demod./ Deinterleaver DM2
Demod./ Deinterleaver DM3
Demod./ Deinterleaver DM4
CW1'
CW2'
CW3'
CW4'
Soft Buffer SB1
Soft Buffer SB2
Soft Buffer SB3
Soft Buffer SB4
Channel Decoder CD1
Channel Decoder CD2
Channel Decoder CD3
Channel Decoder CD4
B1'
B2'
B3'
B4'
Transport Block Combiner 607

Figure 6

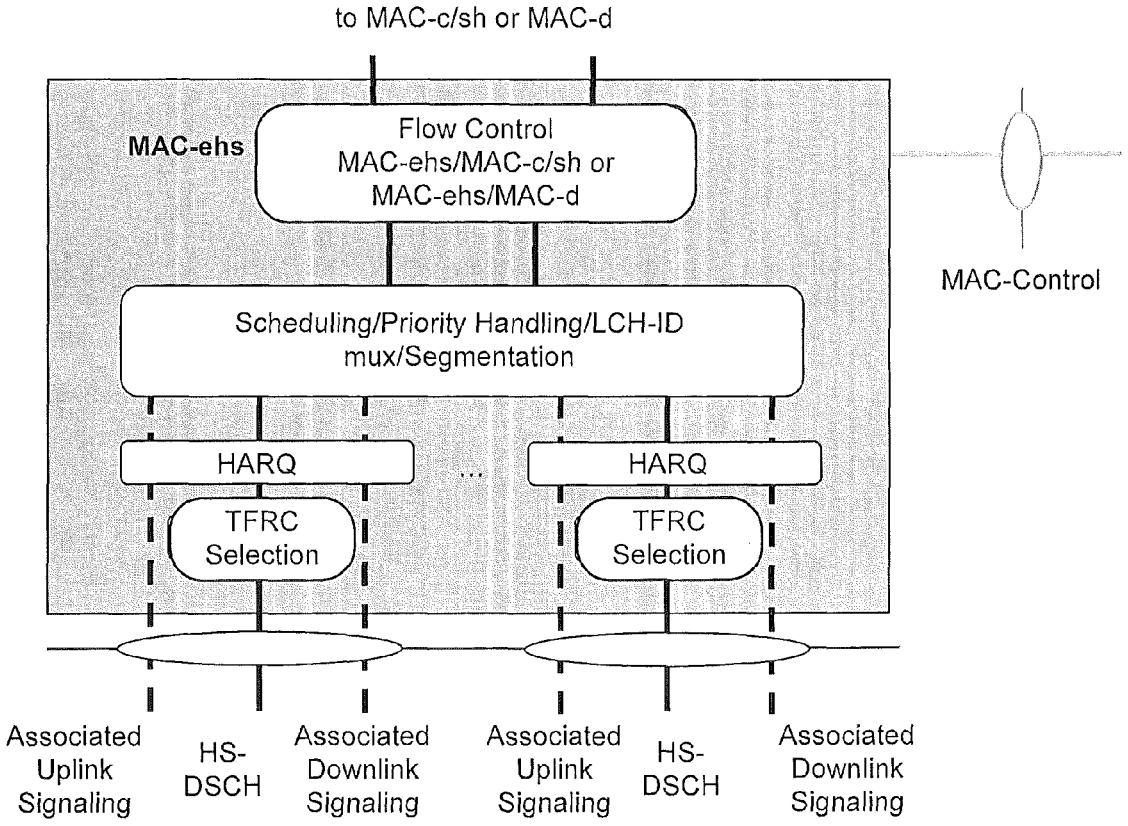

to MAC-c/sh or MAC-d
MAC-ehs
Flow Control
MAC-ehs/MAC-c/sh or
MAC-ehs/MAC-d
MAC-Control
Scheduling/Priority Handling/LCH-ID
mux/Segmentation
HARQ
...
HARQ
TFRC
Selection
TFRC
Selection
Associated
Uplink
Signaling
HS-
DSCH
Associated
Downlink
Signaling
Associated
Uplink
Signaling
HS-
DSCH
Associated
Downlink
Signaling

Figure 7A

	HARQ process	
	1st HARQ	2nd HARQ
4Tx Streams Combinations	Stream 1, Stream 2	Stream 3, Stream 4
	Stream 1, Stream 3	Stream 2, Stream 4
	Stream 1, Stream 4	Stream 2, Stream 3

Figure 7B

	HARQ process	
	1st HARQ	2nd HARQ
3Tx StreamsCombinations	Stream 1, Stream 2	Stream 3
	Stream 1, Stream 3	Stream 2
	Stream 1	Stream 2, Stream 3

Figure 8A

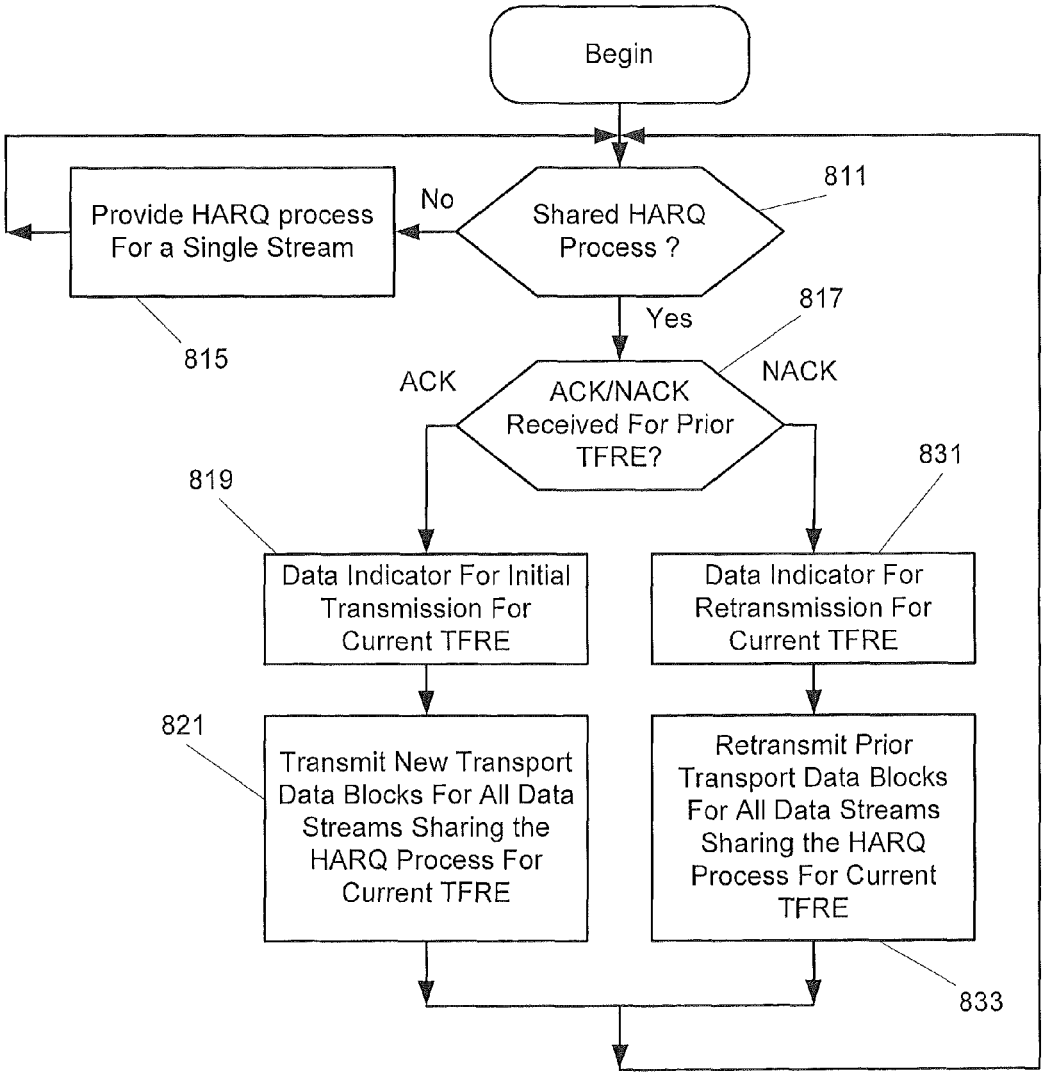

Begin
Shared HARQ Process ?
811
No
Provide HARQ process For a Single Stream
815
Yes
817
ACK
NACK
ACK/NACK Received For Prior TFRE?
819
831
Data Indicator For Initial Transmission For Current TFRE
Data Indicator For Retransmission For Current TFRE
821
Transmit New Transport Data Blocks For All Data Streams Sharing the HARQ Process For Current TFRE
Retransmit Prior Transport Data Blocks For All Data Streams Sharing the HARQ Process For Current TFRE
833

Figure 8B

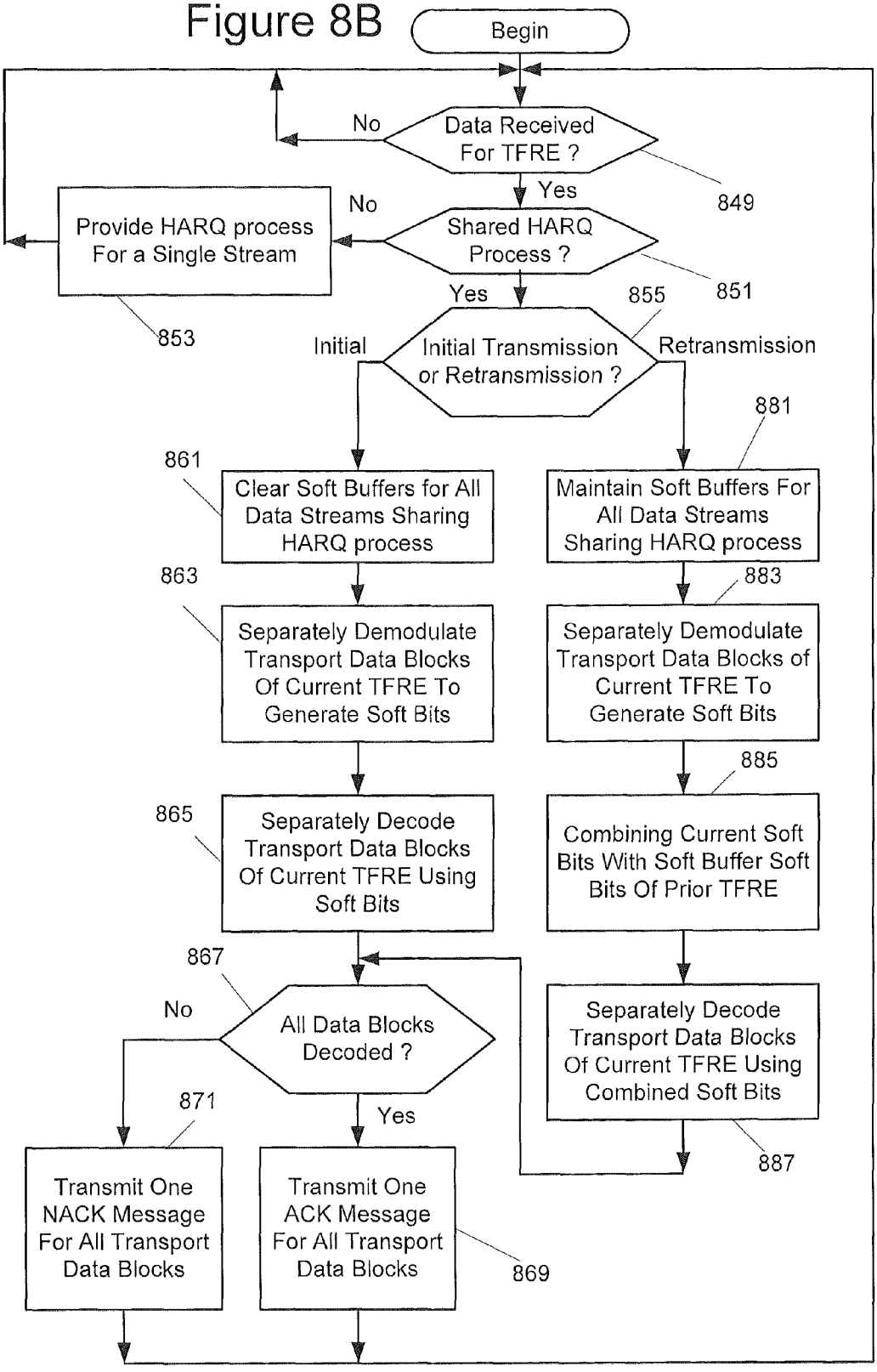

Begin
Data Received For TFRE ?
No
Yes
849
Shared HARQ Process ?
No
Provide HARQ process For a Single Stream
853
Yes
851
855
Initial Transmission or Retransmission ?
Initial
Retransmission
881
861
Clear Soft Buffers for All Data Streams Sharing HARQ process
Maintain Soft Buffers For All Data Streams Sharing HARQ process
863
883
Separately Demodulate Transport Data Blocks Of Current TFRE To Generate Soft Bits
Separately Demodulate Transport Data Blocks of Current TFRE To Generate Soft Bits
885
865
Separately Decode Transport Data Blocks Of Current TFRE Using Soft Bits
Combining Current Soft Bits With Soft Buffer Soft Bits Of Prior TFRE
867
All Data Blocks Decoded ?
No
Yes
Separately Decode Transport Data Blocks Of Current TFRE Using Combined Soft Bits
887
871
Transmit One NACK Message For All Transport Data Blocks
Transmit One ACK Message For All Transport Data Blocks
869

Figure 9

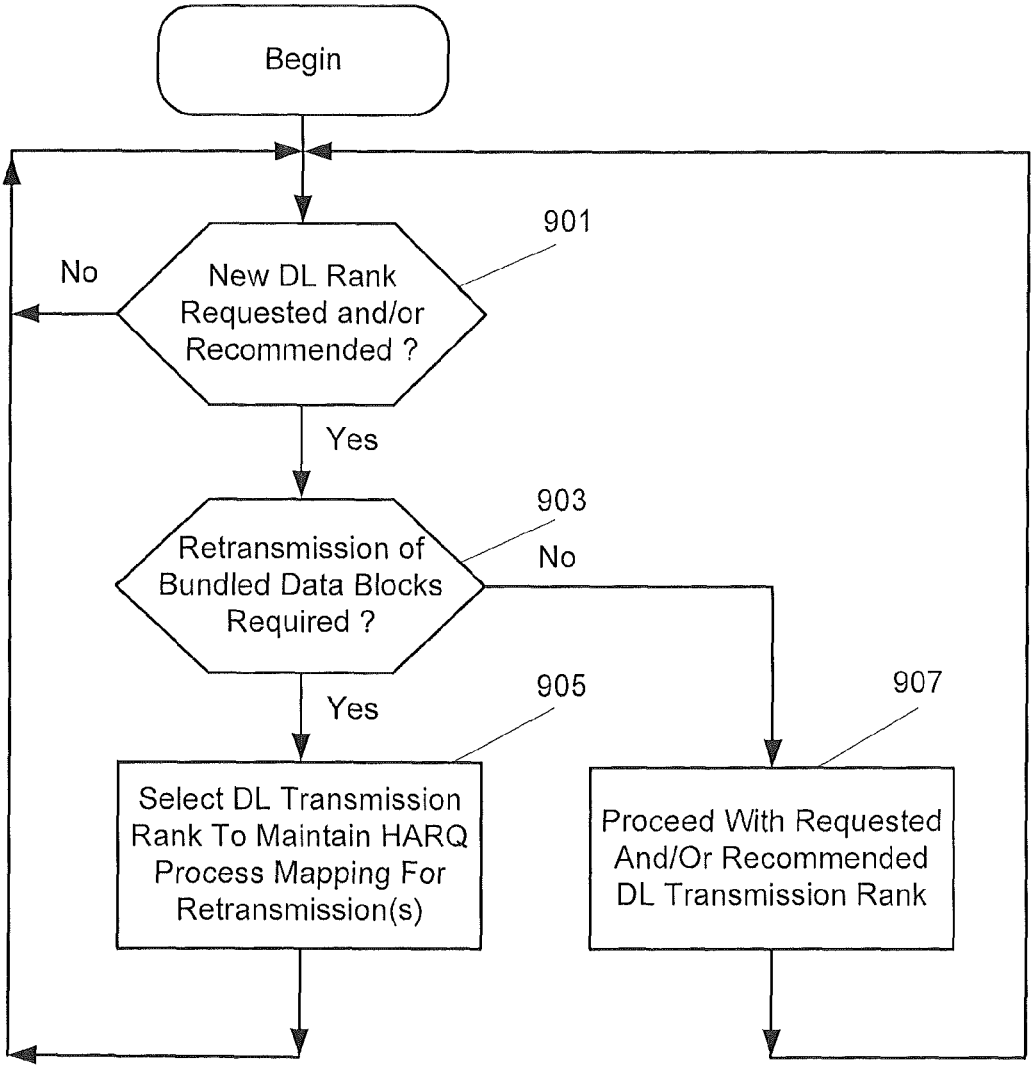

Begin
901
New DL Rank Requested and/or Recommended ?
No
Yes
903
Retransmission of Bundled Data Blocks Required ?
No
Yes
905
907
Select DL Transmission Rank To Maintain HARQ Process Mapping For Retransmission(s)
Proceed With Requested And/Or Recommended DL Transmission Rank

Figure 10

Initial Transmission		Retransmission			
HARQ-1	HARQ-2	UE reported Rank	Scheduled Rank	HARQ-1	HARQ-2
P	--	4	4	NT	NT
F	--	4	2	OT	NT
P	--	3	3	NT	NT
F	--	3	2	OT	NT
P	--	2	2	NT	NT
F	--	2	2	OT	NT
P	--	1	1	NT	---
F	--	1	1	OT	---

Figure 11

Initial Transmission		Retransmission			
HARQ-1	HARQ-2	UE reported Rank	Scheduled Rank	HARQ-1	HARQ-2
P	P	4	4	NT	NT
P	F	4	3	NT	OT
F	P	4	2	OT	NT
F	F	4	2	OT	OT
P	P	3	3	NT	NT
P	F	3	3	NT	OT
F	P	3	1 or 2	OT	--- (with R1) or NT (with R2)
F	F	3	2	OT	OT
P	P	2	2	NT	NT
P	F	2	2	NT	OT
F	P	2	2	OT	NT
F	F	2	2	OT	OT
P	P	1	1	NT	-----
P	F	1	1	------	OT
F	P	1	1	OT	----
F	F	1	2	OT	OT

Figure 12

Initial Transmission		Retransmission			
HARQ-1	HARQ-2	UE reported Rank	Scheduled Rank	HARQ-1	HARQ-2
P	P	3	3	NT	NT
P	F	3	3	NT	OT
F	P	3	3	OT	NT
F	F	3	3	OT	OT
P	P	4	4	NT	NT
P	F	4	3	NT	OT
F	P	4	4	OT	NT
F	F	4	3	OT	OT
P	P	2	2	NT	NT
P	F	2	2	NT	OT
F	P	2	3	OT	NT
F	F	2	3	OT	OT
P	P	1	1	NT	-----
P	F	1	1	------	OT
F	P	1	3	OT	NT
F	F	1	3	OT	OT

Figure 13

Initial Transmission		Retransmission			
HARQ-1	HARQ-2	UE reported Rank	Scheduled Rank	HARQ-1	HARQ-2
P	P	4	4	NT	NT
P	F	4	4	NT	OT
F	P	4	4	OT	NT
F	F	4	4	OT	OT
P	P	3	3	NT	NT
P	F	3	4	NT	OT
F	P	3	3	OT	NT
F	F	3	4	OT	OT
P	P	2	2	NT	NT
P	F	2	4	NT	OT
F	P	2	3	OT	NT
F	F	2	4	OT	OT
P	P	1	1	NT	-----
P	F	1	4	NT	OT
F	P	1	3	OT	NT
F	F	1	4	OT	OT

Figure 14

Rank	Layer	HARQ Process
1	Layer 1 (CW1)	HARQ-1
2	Layer 1 (CW1) Layer 2 (CW2)	HARQ-1 HARQ-2
3	Layer 1 (CW1) Layer 2 (CW2) Layer 3 (CW3)	HARQ-1 HARQ-2
4	Layer 1 (CW1) Layer 4 (CW4) Layer 2 (CW2) Layer 3 (CW3)	HARQ-1 HARQ-2

Figure 15

Initial Transmission		Retransmission			
HARQ-1	HARQ-2	UE reported Rank	Scheduled Rank	HARQ-1	HARQ-2
P	--	4	4	NT	NT
F	--	4	3	OT	NT
P	--	3	3	NT	NT
F	--	3	3	OT	NT
P	--	2	2	NT	NT
F	--	2	2	OT	NT
P	--	1	1	NT	---
F	--	1	1	OT	---

Figure 16

Initial Transmission		Retransmission			
HARQ-1	HARQ-2	UE reported Rank	Scheduled Rank	HARQ-1	HARQ-2
P	P	4	4	NT	NT
P	F	4	2	NT	OT
F	P	4	3	OT	NT
F	F	4	2	OT	OT
P	P	3	3	NT	NT
P	F	3	2	NT	OT
F	P	3	3	OT	NT
F	F	3	2	OT	OT
P	P	2	2	NT	NT
P	F	2	2	NT	OT
F	P	2	2	OT	NT
F	F	2	2	OT	OT
P	P	1	1	NT	-----
P	F	1	2	NT	OT
F	P	1	1	OT	----
F	F	1	2	OT	OT

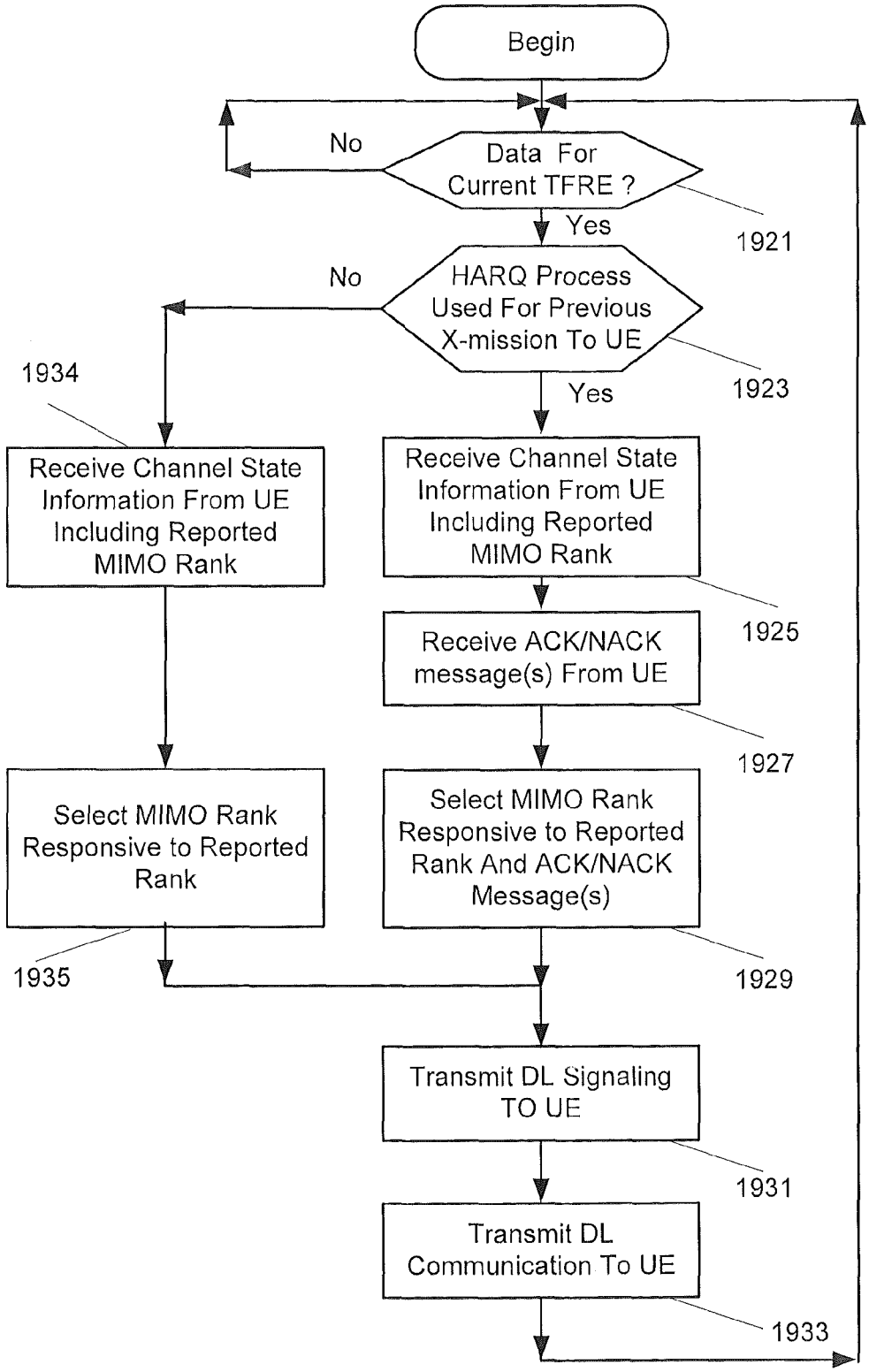
Figure 17

Initial Transmission		Retransmission			
HARQ-1	HARQ-2	UE reported Rank	Scheduled Rank	HARQ-1	HARQ-2
P	P	4	4	NT	NT
P	F	4	4	NT	OT
F	P	4	3	OT	NT
F	F	4	3	OT	OT
P	P	3	3	NT	NT
P	F	3	3	NT	OT
F	P	3	3	OT	NT
F	F	3	3	OT	OT
P	P	2	2	NT	NT
P	F	2	3	NT	OT
F	P	2	2	OT	NT
F	F	2	3	OT	OT
P	P	1	1	NT	-----
P	F	1	3	NT	OT
F	P	1	1	OT	------
F	F	1	3	OT	OT

Figure 18

Initial Transmission		Retransmission			
HARQ-1	HARQ-2	UE reported Rank	Scheduled Rank	HARQ-1	HARQ-2
P	P	4	4	NT	NT
P	F	4	4	NT	OT
F	P	4	4	OT	NT
F	F	4	4	OT	OT
P	P	3	3	NT	NT
P	F	3	3	NT	OT
F	P	3	4	OT	NT
F	F	3	4	OT	OT
P	P	2	2	NT	NT
P	F	2	4	NT	OT
F	P	2	4	OT	NT
F	F	2	4	OT	OT
P	P	1	1	NT	-----
P	F	1	4	NT	OT
F	P	1	4	OT	NT
F	F	1	4	OT	OT

Figure 19


Begin
No
Data For Current TFRE ?
Yes
1921
No
HARQ Process Used For Previous X-mission To UE
Yes
1923
1934
Receive Channel State Information From UE Including Reported MIMO Rank
Receive Channel State Information From UE Including Reported MIMO Rank
1925
Receive ACK/NACK message(s) From UE
1927
Select MIMO Rank Responsive to Reported Rank
Select MIMO Rank Responsive to Reported Rank And ACK/NACK Message(s)
1935
1929
Transmit DL Signaling TO UE
1931
Transmit DL Communication To UE
1933

METHODS OF SELECTING MIMO RANKS AND RELATED DEVICES

CROSS REFERENCE TO RELATED APPLICATION

This application is a 35 U.S.C. §371 national stage application of PCT International Application No. PCT/Sep2013/050133, filed in English on 15 Feb. 2013, which claims priority to U.S. Provisional Application No. 61/615,540 filed on 26 Mar. 2012 and U.S. Provisional Application No. 61/643,491 filed 7 May 2012. The disclosures of all of the above referenced applications are hereby incorporated herein in their entireties by reference.

TECHNICAL FIELD

The present disclosure is directed to wireless communications and, more particularly, to multiple-input-multiple-output (MIMO) wireless communications and related network nodes and wireless terminals.

BACKGROUND

In a typical cellular radio system, wireless terminals (also referred to as user equipment unit nodes, UEs, and/or mobile stations) communicate via a radio access network (RAN) with one or more core networks. The RAN covers a geographical area which is divided into cell areas, with each cell area being served by a radio base station (also referred to as a RAN node, a "NodeB", and/or enhanced NodeB "eNodeB"). A cell area is a geographical area where radio coverage is provided by the base station equipment at a base station site. The base stations communicate through radio communication channels with UEs within range of the base stations.

Moreover, a cell area for a base station may be divided into a plurality of sectors surrounding the base station. For example, a base station may service three 120 degree sectors surrounding the base station, and the base station may provide a respective directional transceiver and sector antenna array for each sector. Stated in other words, a base station may include three directional sector antenna arrays servicing respective 120 degree base station sectors surrounding the base station.

Multi-antenna techniques can significantly increase capacity, data rates, and/or reliability of a wireless communication system as discussed, for example, by Telatar in "Capacity Of Multi-Antenna Gaussian Channels"(European Transactions On Telecommunications, Vol. 10, pp. 585-595, Nov. 1999). Performance may be improved if both the transmitter and the receiver for a base station sector are equipped with multiple antennas (e.g., an sector antenna array) to provide a multiple-input multiple-output (MIMO) communication channel(s) for the base station sector. Such systems and/or related techniques are commonly referred to as MIMO. The LTE standard is currently evolving with enhanced MIMO support and MIMO antenna deployments. A spatial multiplexing mode is provided for relatively high data rates in more favorable channel conditions, and a transmit diversity mode is provided for relatively high reliability (at lower data rates) in less favorable channel conditions.

In a downlink from a base station transmitting from a sector antenna array over a MIMO channel to a wireless terminal in the sector, for example, spatial multiplexing (or SM) may allow the simultaneous transmission of multiple symbol streams over the same frequency from the base station sector antenna array for the sector. Stated in other words, multiple symbol streams may be transmitted from the base station sector antenna array for the sector to the wireless terminal over the same downlink time/frequency resource element (TFRE) to provide an increased data rate. In a downlink from the same base station sector transmitting from the same sector antenna array to the same wireless terminal, transmit diversity (e.g., using space-time codes) may allow the simultaneous transmission of the same symbol stream over the same frequency from different antennas of the base station sector antenna array. Stated in other words, the same symbol stream may be transmitted from different antennas of the base station sector antenna array to the wireless terminal over the same time/frequency resource element (TFRE) to provide increased reliability of reception at the wireless terminal due to transmit diversity gain.

Four layer MIMO transmission schemes are proposed for High-Speed-Downlink-Packet-Access (HSDPA) within Third Generation Partnership Project (3GPP) standardization. Accordingly, up to 4 channel encoded transport data blocks (sometimes referred to as transport data block codewords) may be transmitted using a same TFRE when using 4-branch MIMO transmission. Because ACK/NACK signaling and/or channel encoding for each transport data block to be transmitted during a same TFRE may require wireless terminal feedback (e.g., as ACK/NACK and/or CQI or channel quality information), feedback to define ACK/NACK and/or channel encoding for 4 transport data blocks may be required when using 4-branch MIMO transmission. Feedback signaling when using 4-branch MIMO transmission may thus be undesirably high, for example, because different MIMO layers may be received at a wireless terminal during a same TFRE with different qualities, signal strengths, error rates, etc.

SUMMARY

It may therefore be an object to improve efficiency of transmissions and/or retransmissions in MIMO downlink communications.

According to some embodiments of present inventive concepts, a method of operating a wireless network node (e.g., a base station or NodeB) may include: transmitting a first MIMO downlink communication to a wireless terminal (UE) according to a first MIMO rank; receiving at least one HARQ ACK/NACK message from the wireless terminal (UE) corresponding to the first MIMO downlink communication; receiving a report from the UE identifying a reported MIMO rank; selecting a second MIMO rank for a second MIMO downlink communication responsive to the reported MIMO rank and responsive to the at least one HARQ ACK/NACK message; and transmitting the second MIMO downlink communication to the wireless terminal (UE) according to the second MIMO rank. More particularly, the second MIMO rank may be different that the reported MIMO rank when the at least one HARQ ACK/NACK message includes a NACK message indicating a failure decoding at least one data block of the first MIMO downlink communication. In contrast, the second MIMO rank may be the same as the reported MIMO rank when all of the at least one HARQ ACK/NACK message(s) is/are ACK(s) indicating successful decoding of all data blocks of the first MIMO communication. By considering a HARQ ACK/NACK message for a previous downlink communication when selecting a MIMO rank for a next downlink communication, an efficiency of downlink transmission/retransmission may be improved.

According to some embodiments the wireless network node and wireless terminal may use 4 antenna/branch MIMO

supporting up to four downlink data streams, and two HARQ processes. If the first MIMO downlink communication has rank **2** or higher and both HARQ processes generate NACKs, the first MIMO rank may be maintained as the second downlink rank for the second MIMO downlink communication. If all HARQ processes used in the first MIMO downlink communication generate ACKs, the reported MIMO rank may be selected as the second MIMO rank for the second MIMO downlink communication (including when the first and reported MIMO ranks are different). If a bundled/shared HARQ process is used transmitting the first MIMO downlink communication and the bundled/shared HARQ process generates a NACK, the second MIMO rank may be selected have a rank of three or higher for the next transmission (wherein the second MIMO rank and the reported MIMO rank are different). According to some embodiments, the second MIMO rank may be different that the reported MIMO rank and the second MIMO rank may be different than the first MIMO rank when the at least one HARQ ACK/NACK message includes a NACK message indicating a failure decoding at least one data block of the first MIMO downlink communication.

According to some other embodiments, a method of operating a wireless network may include transmitting a first multiple-input-multiple-output (MIMO) downlink communication to a wireless terminal according to a first MIMO rank, receiving at least one Hybrid Automatic Repeat Request (HARQ) acknowledge/non-acknowledge (ACK/NACK) message from the wireless terminal corresponding to the first MIMO downlink communication, and receiving a report from the wireless terminal identifying a reported MIMO rank. A second MIMO rank may be selected for a second MIMO downlink communication responsive to the at least one HARQ ACK/NACK message, and the second MIMO downlink communication may be transmitted to the wireless terminal according to the second MIMO rank. The second MIMO rank, for example, may be selected for the second MIMO downlink communication responsive to the reported MIMO rank and responsive to the at least one HARQ ACK/NACK message.

If the first MIMO rank is greater than rank **1**, if receiving at least one HARQ ACK/NACK message includes receiving first and second HARQ ACK/NACK messages, and if the first MIMO rank and the reported MIMO rank are different, selecting the second MIMO rank may include selecting the second MIMO rank to be different than the reported MIMO rank responsive to each of the first and second HARQ ACK/NACK messages being a NACK message indicating failure decoding at least one data block of the first MIMO downlink communication.

Selecting the second MIMO rank may include selecting the second MIMO rank to be the same as the reported MIMO rank responsive to all of the HARQ ACK/NACK messages corresponding to the first MIMO downlink communication being ACK messages indicating successful decoding of all data blocks of the first MIMO downlink communication.

Transmitting the first and second MIMO downlink communications may include transmitting the first and second MIMO downlink communications from the wireless network node using a four antenna MIMO antenna array supporting up to four parallel MIMO transmission streams.

The first MIMO rank may be rank **2**, transmitting the first MIMO downlink communication may include transmitting first and second data blocks over respective first and second MIMO transmission layers, and receiving at least one HARQ ACK/NACK message may include receiving first and second HARQ ACK/NACK messages respectively corresponding to the first and second data blocks.

The first MIMO rank may be rank **3**, transmitting the first MIMO downlink communication may include transmitting first, second, and third data blocks over respective first, second, and third MIMO transmission layers, and receiving at least one HARQ ACK/NACK message may include receiving a first HARQ ACK/NACK message corresponding to the first data block and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks.

The first MIMO rank may be rank **4**, transmitting the first MIMO downlink communication may include transmitting first, second, third, and fourth data blocks over respective first, second, third, and fourth MIMO layers, and receiving at least one HARQ ACK/NACK message may include receiving a first HARQ ACK/NACK message corresponding to the first and fourth data blocks and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks.

If the first MIMO rank is at least rank **2** and the reported MIMO rank is different than the first MIMO rank, selecting the second MIMO rank may include selecting the second MIMO rank to be the same as the reported MIMO rank responsive to the first and second HARQ ACK/NACK messages being ACK messages.

If the first MIMO rank is rank **4** and the reported MIMO rank is less than rank **3**, selecting the second MIMO rank may include selecting the second MIMO rank to be different than the reported MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message.

If the first MIMO rank is rank **2** and the reported MIMO rank is rank **4**, selecting the second MIMO rank may include selecting the second MIMO rank to be different than the reported MIMO rank and different than the first MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message.

If the first MIMO rank is at least rank **2** and the reported MIMO rank is different than the first MIMO rank, selecting the second MIMO rank may include selecting the second MIMO rank to be the same as first MIMO rank responsive to both of the first and second HARQ ACK/NACK messages being NACK messages.

If the first MIMO rank is at least rank **2** and the reported MIMO rank is different than the first MIMO rank, the second MIMO rank may be selected to be the same as the reported MIMO rank responsive to the first and second HARQ ACK/NACK messages being ACK messages, and the second MIMO rank may be selected to be the same as first MIMO rank responsive to both of the first and second HARQ ACK/NACK messages being NACK messages.

If the first MIMO rank is rank **1**, transmitting the first MIMO downlink communication may include transmitting a first data block over a first MIMO layer, and receiving at least one HARQ ACK/NACK message may include receiving a first HARQ ACK/NACK message corresponding to the first data block.

According to still other embodiments, a wireless network node may include a transceiver configured to transmit and/or receive communications over a wireless channel and a processor coupled to the transceiver. The processor may be configured to transmit a first multiple-input-multiple-output (MIMO) downlink communication through the transceiver to a wireless terminal according to a first MIMO rank and to receive at least one Hybrid Automatic Repeat Request (HARQ) acknowledge/non-acknowledge (ACK/NACK) message from the wireless terminal through the transceiver

corresponding to the first MIMO downlink communication. The processor may also be configured to receive a report from the wireless terminal through the transceiver identifying a reported MIMO rank, to select a second MIMO rank for a second MIMO downlink communication responsive to the at least one HARQ ACK/NACK message, and to transmit the second MIMO downlink communication through the transceiver to the wireless terminal according to the second MIMO rank. The processor, for example, may select the second MIMO rank for the second MIMO downlink communication responsive to the reported MIMO rank and responsive to the at least one HARQ ACK/NACK message.

If the first MIMO rank is greater than rank **1**, if receiving at least one HARQ ACK/NACK message includes receiving first and second HARQ ACK/NACK messages, and if the first MIMO rank and the reported MIMO rank are different, the processor may be configured to select the second MIMO rank to be different than the reported MIMO rank responsive to each of the first and second HARQ ACK/NACK messages being a NACK message.

The processor may be configured to select the second MIMO rank to be the same as the reported MIMO rank responsive to all of the HARQ ACK/NACK messages corresponding to the first MIMO downlink communication being ACK messages indicating successful decoding of all data blocks of the first MIMO downlink communication.

The transceiver may be configured to transmit the first and second MIMO downlink communications using a four antenna MIMO antenna array supporting up to four parallel MIMO transmission streams.

The first MIMO rank may be rank **2**, the processor may be configured to transmit the first MIMO downlink communication through the transceiver by transmitting first and second data blocks over respective first and second MIMO layers, and the processor may be configured to receive at least one HARQ ACK/NACK message through the transceiver by receiving first and second HARQ ACK/NACK messages respectively corresponding to the first and second data blocks.

The first MIMO rank may be rank **3**, the processor may be configured to transmit the first MIMO downlink communication through the transceiver by transmitting first, second, and third data blocks over respective first, second, and third MIMO layers, and the processor may be configured to receive at least one HARQ ACK/NACK message through the transceiver by receiving a first HARQ ACK/NACK message corresponding to the first data block and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks.

The first MIMO rank may be rank **4**, the processor may be configured to transmit the first MIMO downlink communication through the transceiver by transmitting first, second, third, and fourth data blocks over respective first, second, third, and fourth MIMO layers, and the processor may be configured to receive at least one HARQ ACK/NACK message through the transceiver by receiving a first HARQ ACK/NACK message corresponding to the first and fourth data blocks and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks.

If the first MIMO rank is at least rank **2** and the reported MIMO rank is different than the first MIMO rank, the processor may be configured to select the second MIMO rank to be the same as the reported MIMO rank responsive to the first and second HARQ ACK/NACK messages being ACK messages.

If the first MIMO rank is rank **4** and the reported MIMO rank is less than rank **3**, the processor may be configured to select the second MIMO rank to be different than the reported MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message.

If the first MIMO rank is rank **2** and the reported MIMO rank is rank **4**, the processor may be configured to select the second MIMO rank to be different than the reported MIMO rank and different than the first MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message.

If the first MIMO rank is at least rank **2** and the reported MIMO rank is different than the first MIMO rank, the processor may be configured to select the second MIMO rank to be the same as first MIMO rank responsive to both of the first and second HARQ ACK/NACK messages being NACK messages.

If the first MIMO rank is at least rank **2** and the reported MIMO rank is different than the first MIMO rank, the processor may be configured to select the second MIMO rank to be the same as the reported MIMO rank responsive to the first and second HARQ ACK/NACK messages being ACK messages, and to select the second MIMO rank to be the same as first MIMO rank responsive to both of the first and second HARQ ACK/NACK messages being NACK messages.

The first MIMO rank may be rank **1**, the processor may be configured to transmit the first MIMO downlink communication through the transceiver by transmitting a first data block over a first MIMO layer, and the processor may be configured to receive at least one HARQ ACK/NACK message through the transceiver by receiving a first HARQ ACK/NACK message corresponding to the first data block.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the disclosure and are incorporated in and constitute a part of this application, illustrate certain non-limiting embodiment(s) of present inventive concepts. In the drawings:

FIG. **1** is a block diagram of a communication system that is configured according to some embodiments;

FIG. **2** is a block diagram illustrating a base station and a wireless terminal according to some embodiments of FIG. **1**;

FIG. **3**A is a message sequence chart for a MIMO communication system;

FIG. **3**B is illustrates a feedback channel report format of FIG. **3**A;

FIG. **4** is a block diagram illustrating elements/functionalities of base station processors according to some embodiments of FIG. **2**;

FIG. **5** is a block diagram illustrating elements/functionalities of wireless terminal processors according to some embodiments of FIG. **2**;

FIG. **6** illustrates schematically a medium access control (MAC) entity in a wireless terminal (UE);

FIGS. **7**A and **7**B are tables illustrating combinations of sharing HARQ processes between multiple MIMO data streams for rank/layer **3** and **4** MIMO transmissions;

FIGS. **8**A and **8**B are flow charts illustrating operations of base stations and wireless terminals according to some embodiments;

FIG. **9** is a flow chart illustrating base station operations according to some embodiments;

FIG. **10** is a table illustrating MIMO rank selection with an initial transmission rank equal to one according to some embodiments;

FIG. **11** is a table illustrating MIMO rank selection with an initial transmission rank equal to two according to some embodiments;

FIG. **12** is a table illustrating MIMO rank selection with an initial transmission rank equal to three according to some embodiments;

FIG. **13** is a table illustrating MIMO rank selection with an initial transmission rank equal to four according to some embodiments;

FIG. **14** is a table illustrating allocations of two HARQ processes to MIMO data layers/streams for rank **1**, **2**, **3**, and **4** MIMO transmission/reception according to some other embodiments;

FIG. **15** is a table illustrating MIMO rank selection with an initial transmission rank equal to one according to some embodiments;

FIG. **16** is a table illustrating MIMO rank selection with an initial transmission rank equal to two according to some embodiments;

FIG. **17** is a table illustrating MIMO rank selection with an initial transmission rank equal to three according to some embodiments;

FIG. **18** is a table illustrating MIMO rank selection with an initial transmission rank equal to four according to some embodiments; and

FIG. **19** is a flow chart illustrating base station operations according to some embodiments.

DETAILED DESCRIPTION

Inventive concepts will now be described more fully hereinafter with reference to the accompanying drawings, in which examples of embodiments of present inventive concepts are shown. Inventive concepts may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of present inventive concepts to those skilled in the art. It should also be noted that these embodiments are not mutually exclusive. Components from one embodiment may be tacitly assumed to be present/used in another embodiment.

For purposes of illustration and explanation only, these and other embodiments of present inventive concepts are described herein in the context of operating in a RAN that communicates over radio communication channels with wireless terminals (also referred to as UEs). It will be understood, however, that present inventive concepts are not limited to such embodiments and may be embodied generally in any type of communication network. As used herein, a wireless terminal (also referred to as a UE) can include any device that receives data from a communication network, and may include, but is not limited to, a mobile telephone ("cellular" telephone), laptop/portable computer, pocket computer, hand-held computer, and/or desktop computer.

In some embodiments of a RAN, several base stations can be connected (e.g., by landlines or radio channels) to a radio network controller (RNC). The radio network controller, also sometimes termed a base station controller (BSC), supervises and coordinates various activities of the plural base stations connected thereto. The radio network controller is typically connected to one or more core networks.

The Universal Mobile Telecommunications System (UMTS) is a third generation mobile communication system, which evolved from the Global System for Mobile Communications (GSM), and is intended to provide improved mobile communication services based on Wideband Code Division Multiple Access (WCDMA) technology. UTRAN, short for UMTS Terrestrial Radio Access Network, is a collective term for the Node B's and Radio Network Controllers which make up the UMTS radio access network. Thus, UTRAN is essentially a radio access network using wideband code division multiple access for UEs.

The Third Generation Partnership Project (3GPP) has undertaken to further evolve the UTRAN and GSM based radio access network technologies. In this regard, specifications for the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) are ongoing within 3GPP. The Evolved Universal Terrestrial Radio Access Network (E-UTRAN) comprises the Long Term Evolution (LTE) and System Architecture Evolution (SAE).

Note that although terminology from 3GPP (3^{rd} Generation Partnership Project) LTE (Long Term Evolution) is used in this disclosure to exemplify embodiments of present inventive concepts, this should not be seen as limiting the scope of present inventive concepts to only these systems. Other wireless systems, including WCDMA (Wideband Code Division Multiple Access), WiMax (Worldwide Interoperability for Microwave Access), UMB (Ultra Mobile Broadband), HSDPA (High-Speed Downlink Packet Access), GSM (Global System for Mobile Communications), etc., may also benefit from exploiting embodiments of present inventive concepts disclosed herein.

Also note that terminology such as base station (also referred to as eNodeB or Evolved Node B) and wireless terminal (also referred to as UE or User Equipment) should be considering non-limiting and does not imply a certain hierarchical relation between the two. In general a base station (e.g., an "eNodeB") and a wireless terminal (e.g., a "UE") may be considered as examples of respective different communications devices that communicate with each other over a wireless radio channel. While embodiments discussed herein may focus on wireless transmissions in a downlink from an eNodeB to a UE, embodiments of present inventive concepts may also be applied, for example, in the uplink.

FIG. **1** is a block diagram of a communication system that is configured to operate according to some embodiments of present inventive concepts. An example RAN **60** is shown that may be a Long Term Evolution (LTE) RAN. Radio base stations (e.g., eNodeBs) **100** may be connected directly to one or more core networks **70**, and/or radio base stations **100** may be coupled to core networks **70** through one or more radio network controllers (RNC). In some embodiments, functionality of a radio network controller(s) may be performed by radio base stations **100**. Radio base stations **100** communicate over wireless channels **300** with wireless terminals (also referred to as user equipment nodes or UEs) **200** that are within their respective communication service cells (also referred to as coverage areas). The radio base stations **100** can communicate with one another through an X2 interface and with the core network(s) **70** through Si interfaces, as is well known to one who is skilled in the art.

FIG. **2** is a block diagram of a base station **100** and a wireless terminal **200** of FIG. **1** in communication over wireless channel **300** according to some embodiments of present inventive concepts. As shown, base station **100** may include transceiver **109** coupled between processor **101** and antenna array **117** (including multiple antennas), and memory **118** coupled to processor **101**. Moreover, wireless terminal **200** may include transceiver **209** coupled between antenna array **217** and processor **201**, and user interface **221** and memory **218** may be coupled to processor **201**. Accordingly, base station processor **101** may transmit communications through transceiver **109** and antenna array **117** for reception at wire-

less terminal processor **201** through antenna array **217** and transceiver **209**. In the other direction, wireless terminal processor **201** may transmit communications through transceiver **209** and antenna array **217** for reception at base station processor **101** through antenna array **117** and transceiver **109**. To support up to 4-branch MIMO (allowing parallel transmission of 4 layers/streams of data using a same TFRE), each of antenna arrays **117** and **217** may include four (or more) antenna elements. Wireless terminal **200** of FIG. **2**, for example, may be a cellular radiotelephone, a smart phone, a laptop/netbook/tablet/handheld computer, or any other device providing wireless communications. User interface **211**, for example, may include a visual display such as an liquid crystal display, a touch sensitive visual display, a keypad, a speaker, a microphone, etc.

For MIMO downlink transmissions from RAN **60** to wireless terminal **200**, a codebook of precoding vectors (known at both RAN **60** and wireless terminal **200**) is used to precode (e.g., to apply precoding weights to) the different data layers (data streams) that are transmitted in parallel from a sector antenna array(s) to the wireless terminal **200** during a same TFRE, and to decode the data layers (data streams) received in parallel during the same TFRE at wireless terminal **200**. The same codebook of precoding vectors may be stored in wireless terminal memory **218** and in base station memory **118**. Moreover, wireless terminal **200** may estimate characteristics of each downlink channel to generate channel quality information (CQI), and CQI feedback from wireless terminal **200** may be transmitted to base station **100**. This CQI feedback may then be used by the base station processor **101** to select: transmission rank (i.e., a number of data layers/streams to be transmitted during a subsequent TFRE); transport data block length(s); channel code rate(s) to be used to channel encode different transport data blocks; modulation order(s); symbol to layer mapping schemes; and/or precoding vectors for respective downlink transmissions to the wireless terminal **200**.

By way of example, base station antenna array **117** may include 4 antennas and wireless terminal antenna array **217** may include four antennas so that wireless terminal **200** may receive up to four downlink data layers (data streams) from base station antenna array **117** during MIMO communications. In this example, the precoding codebook may include rank **1** precoding vectors (used when transmitting one downlink data stream from a base station sector antenna array **117** to wireless terminal **200**), rank **2** precoding vectors (used when transmitting two downlink data streams from a base station sector antenna array **117** to wireless terminal **200**), rank **3** precoding vectors (used when transmitting three downlink data streams from a base station sector antenna array **117** to wireless terminal **200**), and rank **4** precoding vectors (used when transmitting four downlink data streams from a base station sector antenna array **117** to wireless terminal **200**). Precoding vectors may also be referred to, for example, as precoding codebook entries, precoding codewords, and/or precoding matrices.

An issue for four layer MIMO transmission schemes for HSDPA is what number of HARQ (Hybrid Automatic Repeat Request) codewords/processes should be supported. To reduce uplink and/or downlink signaling, two HARQ codewords/processes may be used in four layer MIMO transmission schemes for feedback relating to one, two, three, and four layer downlink transmissions. Use of two HARQ codewords/processes may be relatively easier to implement without significantly reducing performance (relative to use of four HARQ codewords/processes).

A Hybrid Automatic Repeat Request (HARQ) process(es) may be used in a wireless system to overcome transmission errors that cannot be corrected using a forward error correction code (also referred to as a channel code) alone. In some embodiments of a HARQ process, the HARQ process is mapped to one or more MIMO transmission layers, and the transmitting device (e.g., base station **100**) attaches an error detection/correction code (e.g., a cyclic redundancy check or CRC code) to each transport data block (also referred to as a data block, data packet, packet, etc.) of a TTI/TFRE to provide error detection/correction, and the resulting data block including the error detection/correction code may be referred to as a data codeword CW. At the receiving device (e.g., at wireless terminal **200**), the contents of each received transport data block may be validated using the respective error detection/correction code attached thereto. If the transport data block fails the error detection/correction validation, the receiving device may send a HARQ codeword including a negative acknowledgement NACK message (also referred to as a non-acknowledgement message) for the HARQ process back to the transmitting device to request a retransmission of the failed transport data block or blocks mapped to the HARQ process. A failed data block may be retransmitted until it is either decoded or until a maximum number of allowed retransmissions (e.g., four to six retransmissions) have occurred. If the transport data block passes the error detection/correction validation, a HARQ codeword including an acknowledgement ACK message for the HARQ process is sent back to the transmitting device to acknowledge reception and correct decoding of the transport data block. A HARQ process may thus be mapped to one or more MIMO transmission layers, and for each TTI/TFRE, the HARQ process may generate a HARQ ACK/NACK feedback message that is transmitted in a HARQ codeword of the feedback channel (e.g. HS-PDCCH).

As discussed in greater detail below, a wireless terminal **200** implementing HARQ functionality may include a soft buffer for each transport data block received during a TFRE so that originally transmitted and retransmitted transport data blocks may be combined before decoding to thereby improve system throughput. Depending on the way the originally transmitted and retransmitted transport data blocks are combined. HARQ systems/processes may be classified as chase combining or CC (retransmitting the same transport data block without additional information) or Incremental Redundancy or IR (transmitting the same transport data block with additional parity bits).

A single soft buffer may be used for layer/rank one MIMO transmission/reception (with one transport data block received during a TFRE), two soft buffers may be used for layer/rank two MIMO transmission/reception (with two transport data blocks received during a TFRE), three soft buffers may be used for layer/rank three MIMO transmission/reception (with three transport data blocks received during a TFRE), and four soft buffers may be used for layer/rank four MIMO transmission/reception (with four transport data blocks received during a TFRE). Each soft buffer stores a demodulator output for a transport data block before decoding to be used after a retransmission if the transport data block is not successfully decoded. For Release 7 MIMO supporting up to two rank/layer transmissions (with up to two transport data blocks transmitted to a UE during a TFRE), a HARQ process—is provided for each soft buffer and thus for each transport data block. When two HARQ processes are mapped to three or four layer/rank MIMO transmission/reception, however, a mechanism to map UE receiver soft buffers to HARQ processes—may be needed.

According to some embodiments discussed herein, methods may be provided to map functionalities between base station **100** transmission layers, wireless terminal **200** receiver layers (including respective soft buffers), and HARQ processes for situations when the number of supported HARQ processes is less than a number of MIMO transmission layers/ranks supported by the system (e.g., when rank/layer **3** and/or **4** MIMO transmissions are supported but only two HARQ processes are supported). With two HARQ processes, both HARQ ACK/NACK messages may be included in a HARQ codeword of the feedback channel (e.g. HS-DPCCH).

FIG. **3**A illustrates a message sequence between base station **100** and wireless terminal **200** in a MIMO communications system. As shown in FIG. **3**A, base station **100** transmits pilot signals over the downlink channel(s), and wireless terminal **200** estimates the downlink channel(s) at block **391** (for transmissions from base station **100** to wireless terminal **200**) based on the pilot signals. Wireless terminal **200** generates (e.g., computes) channel state information at block **393** for the downlink channel(s), and wireless terminal **200** reports the channel state information to base station **100** over a feedback channel. An example of a format for a feedback channel report for two reporting intervals is illustrated in FIG. **3**B, and FIG. **3**B shows that the feedback channel report may include a HARQ element/message/codeword (including acknowledge/ACK and/or negative-acknowledge/NACK information) and/or CQI/PCI (channel quality information and/or precoding control indicator) information.

More particularly, wireless terminal **200** may transmit CQI/PCI information (over the feedback channel) including a rank indicator requesting/recommending a MIMO transmission rank for subsequent downlink transmissions from base station **100** to wireless terminal **200**. Base station processor **101** may select the requested/recommended MIMO rank or a different MIMO rank, and base station **100** may identify the selected MIMO rank in downlink signaling transmitted to wireless terminal **200**. Base station **100** may then transmit one or more transport data blocks using respective MIMO streams over the downlink channel in a subsequent TFRE in accordance with the selected MIMO rank as downlink traffic. Based on success/failure decoding each received transport data block, wireless terminal **200** may generate respective HARQ ACK/NACK messages that are transmitted to base station **100** over the feedback channel.

FIG. **4** is block diagram illustrating elements/functionalities of base station processor **101** of FIG. **2** supporting two HARQ codeword MIMO with 4 channel encoders and up to four rank MIMO downlink transmission according to some embodiments. According to embodiments of FIG. **4**, four channel encoders CE**1**, CE**2**, CE**3**, and CE**4** may be provided for four streams of transport data blocks B**1**, B**2**, B**3**, and B**4**, with symbols of one data input stream for wireless terminal **200** being mapped to as many as four different data streams. As shown, processor **101** may include transport data block generator **401**, channel encoder **403**, modulator **405**, layer mapper **407**, spreader/scrambler **409**, and layer precoder **411**. In embodiments of FIG. **4**, channel encoder **403** may include channel encoders CE**1**, CE**2**, CE**3**, and CE**4** for the four streams of transport data blocks B**1**, B**2**, B**3**, and B**4**, modulator **405** may include interleavers/modulators IM**1**, IM**2**, IM**3**, and IM**4**, and layer mapper **407** may be configured to map resulting symbols of the four streams to as many as four different MIMO layers (streams) X**1**, X**2**, X**3**, and X**4** as discussed in greater detail below. Moreover, adaptive controller **415** may be configured to control transport data block generator **401**, channel encoder **403**, modulator **405**, layer mapper **407**, and/or layer precoder **411** responsive to channel quality information (CQI) received as feedback from wireless terminal **200**. Accordingly, symbols generated responsive to codewords respectively generated by channel encoders CE**1**, CE**2**, CE**3**, and CE**4** using different channel coding (determined by adaptive controller **415** responsive to wireless terminal **200** feedback) may be interleaved and distributed (mapped) to 4 different MIMO layers. More particularly, symbols generated responsive to two data codewords CW (where a data codeword CW is a transport data block with additional channel coding and/or CRC bits) may be interleaved and then split between two different MIMO layers. According to some embodiments discussed herein layer mapper **407** may perform a one-to-one mapping.

Base station processor **101** for example, may receive input data (e.g., from core network **70**, from another base station, etc.) for transmission to wireless terminal **200**, and transport data block generator **401** (including transport data block data generators TB**1**, TB**2**, TB**3**, and TB**4**) may provide a single stream of data blocks (for rank **1** transmissions) or separate the input data into a plurality of different streams of data blocks (for rank **2**, rank **3**, and rank **4** transmission). More particularly, for rank **1** transmissions (providing only 1 MIMO layer/stream), all input data may be processed through transport data block generator TB**1** to provide a single stream of transport data blocks B**1** (including individual transport data blocks b**1**-**1**, b**1**-**2**, b**1**-**3**, etc.) without using transport data block generators TB**2**, TB**3**, or TB**4** and without generating other streams of transport data blocks B**2**, B**3**, or B**4**. For rank **2** transmissions (providing 2 MIMO layers/streams), transport data block generator TB**1** may generate a stream of transport data blocks B**1** (including individual transport data blocks b**1**-**1**, b**1**-**2**, b**1**-**3**, etc.), and transport data block generator TB**3** may generate a stream of transport data blocks B**3** (including individual transport data blocks b**3**-**1**, b**3**-**2**, b**3**-**3**, etc.) without using transport data block generators TB**2** or TB**4** and without generating other streams of transport data blocks B**2** or B**4**. For rank **3** transmissions (providing 3 MIMO layers/streams), transport data block generator TB**1** may generate a stream of transport data blocks B**1** (including individual transport data blocks b**1**-**1**, b**1**-**2**, b**1**-**3**, etc.), transport data block generator TB**2** may generate a stream of transport data blocks B**2** (including individual transport data blocks b**2**-**1**, b**2**-**2**, b**2**-**3**, etc.), and transport data block generator TB**3** may generate a stream of transport data blocks B**3** (including individual transport data blocks b**3**-**1**, b**3**-**2**, b**3**-**3**, etc.), without using transport data block generator TB**4** and without generating another stream of transport data blocks B**4**. For rank **4** transmissions (providing 4 MIMO layers/streams), transport data block generator TB**1** may generate a stream of transport data blocks B**1** (including individual transport data blocks b**1**-**1**, b**1**-**2**, b**1**-**3**, etc.), transport data block generator TB**2** may generate a stream of transport data blocks B**2** (including individual transport data blocks b**2**-**1**, b**2**-**2**, b**2**-**3**, etc.), transport data block generator TB**3** may generate a stream of transport data blocks B**3** (including individual transport data blocks b**3**-**1**, b**3**-**2**, b**3**-**3**, etc.), and transport data block generator TB**4** may generate a stream of transport data blocks B**4** (including individual transport data blocks b**4**-**1**, b**4**-**2**, b**4**-**3**, etc.).

Channel encoder **403** (including channel encoders CE**1**, CE**2**, CE**3**, and CE**4**) may encode the stream/streams of data blocks B**1**, B**2**, B**3**, and/or B**4** generated by transport data block generator **401** to provide respective streams of data codewords CW**1** (including individual codewords cw**1**-**1**, cw**1**-**2**, cw**1**-**3**, etc.), CW**2** (including individual data codewords cw**2**-**1**, cw**2**-**2**, cw**2**-**3**, etc.), CW**3** (including individual

data codewords cw3-1, cw3-2, cw3-3, etc.), and/or CW4 (including individual data codewords cw4-1, cw4-2, cw4-3, etc.), for example, using turbo coding, convolutional coding, etc. Moreover, coding characteristics (e.g., coding rates) applied by channel encoders CE1, CE2, CE3, and CE4 may be separately determined by adaptive controller **415** responsive to wireless terminal **200** feedback (e.g., CQI regarding the downlink channel). For rank 1 transmissions, channel encoder **403** may generate a single stream of data codewords CW1 responsive to the stream of data blocks B1 using only channel encoder CE1. For rank 2 transmissions, channel encoder **403** may generate two streams of data codewords CW1 and CW3 responsive to respective streams of data blocks B1 and B3 using channel encoder CE1 and channel encoder CE3. For rank 3 transmissions, channel encoder **403** may generate three streams of data codewords CW1. CW2, and CW3 responsive to respective streams of data blocks B1, B2, and B3 using channel encoder CE1, channel encoder CE2, and channel encoder CE3. For rank 4 transmissions, channel encoder **403** may generate four streams of data codewords CW1, CW2, CW3, and CW4 responsive to respective streams of data blocks B1, B2, B3, and B4 using channel encoder CE1, channel encoder CE2, channel encoder CE3, and channel encoder CE4. According to some embodiments, channel encoders CE1, CE2, CE3, and/or may apply different coding characteristics (e.g., different coding rates) during rank 2, rank 3, and/or rank 4 transmissions to generate respective (differently coded) data codewords cw1-1, cw2-1, cw3-1, and/or cw4-1 including data to be transmitted during a same TF

Modulator **405** (including interleaver/modulators IM1, IM2, IM3, and IM4) may interleave and modulate the stream/streams of data codewords CW1, CW2, CW3, and/or CW4 generated by channel encoder **403** to provide respective streams of unmapped symbol blocks D1 (including unmapped symbol blocks d1-1, d1-2, d1-3, etc.), D2 (including unmapped symbol blocks d2-1, d2-2, d2-3, etc.), D3 (including unmapped symbol blocks d3-1, d3-2, d3-3, etc.), and/or D4 (including unmapped symbol blocks d4-1, d4-2, d4-3, etc.). For rank 1 transmissions (providing only 1 MIMO layer/stream), modulator **405** may generate a single stream of unmapped symbol blocks D1 responsive to the stream of data codewords CW1 using only interleaver/modulator IM1. For rank 2 transmissions, modulator **405** may generate two streams of unmapped symbol blocks D1 and D3 responsive to respective streams of data codewords CW1 and CW3 using interleaver/modulators IM1 and IM3. For rank 3 transmissions, modulator **405** may generate three streams of unmapped symbol blocks D1, D2, and D3 responsive to respective streams of data codewords CW1, CW2, and CW3 using interleaver/modulators IM1, IM2, and IM3. For rank 4 transmissions, modulator **405** may generate four streams of unmapped symbol blocks D1, D2, D3, and D4 responsive to respective streams of data codewords CW1, CW2, CW3, and CW4 using interleaver/modulators IM1, IM2, IM3, and IM4. Modulator **405** may apply modulation orders responsive to input from adaptive controller **415** determined based on CQI feedback from wireless terminal **200**.

In addition, each interleaver/modulator IM1, IM2, IM3, and/or IM4 may interleave data of two or more codewords of a stream so that two or more consecutive unmapped symbol blocks of a respective stream include symbols representing data of the two or more consecutive codewords. For example, data of consecutive data codewords cw1-1 and cw1-2 of data codeword stream CW1 may be interleaved and modulated to provide consecutive unmapped symbol blocks d1-1 and d1-2 of stream D1. Similarly, data of consecutive data codewords cw2-1 and cw2-2 of data codeword stream CW2 may be interleaved and modulated to provide consecutive unmapped symbol blocks d2-1 and d2-2 of stream D2; data of consecutive data codewords cw3-1 and cw3-2 of data codeword stream CW3 may be interleaved and modulated to provide consecutive unmapped symbol blocks d3-1 and d3-2 of stream D3; and/or data of consecutive data codewords cw4-1 and cw4-2 of data codeword stream CW4 may be interleaved and modulated to provide consecutive unmapped symbol blocks d4-1 and d4-2 of stream D4.

Symbols of streams of unmapped symbol blocks D1, D2, D3, and D4 may be mapped to respective streams of mapped symbol blocks X1, X2, X3, and X4 (for respective MIMO transmission layers), for example, using a one-to-one mapping. While one-to-one mapping is discussed by way of example, other mappings may be used provided that the mapping function of layer mapper **407** is known to both base station **100** and wireless terminal **200**.

Spreader/scrambler **409** may include four spreader/scramblers SS1, SS2, SS3, and SS4, and for each mapped symbol stream provided by layer mapper **407**, spreader/scrambler **409** may generate a respective stream of spread symbol blocks Y1, Y2, Y3, and Y4 (e.g., using a Walsh code). Layer precoder **411** may apply a MIMO precoding vector (e.g., by applying precoding weights) of the appropriate rank (based on wireless terminal feedback as interpreted by adaptive controller **415**) to the streams of spread symbol blocks for transmission through transceiver **109** and antennas Ant-1, Ant-2, Ant-3, and Ant-4 of antenna array **117**. According to some embodiments, with rank one transmissions, only first layer of elements (e.g., TB1, CE1, IM1, and/or SS1) of FIG. **4** may be used; with rank two transmissions, two layers of elements (e.g., TB1, TB3, CE1, CE3, IM1, IM3, SS1, and/or SS3) of FIG. **4** may be used; with rank three transmissions, three layers of elements (e.g., TB1, TB2, TB3, CE1, CE2, CE3, IM1, IM2, IM3, SS1, SS2, and/or SS3) of FIG. **4** may be used; and with rank four transmissions, four layers of elements (e.g., TB1, TB2, TB3, TB4, CE1, CE2, CE3, CE4, IM1, IM2, IM3, and IM4, SS1, SS2, SS3, and/or SS4) of FIG. **4** may be used. According to some other embodiments, with rank one transmissions, only a first layer of elements (e.g., TB1, CE1, IM1, and/or SS1) of FIG. **4** may be used; with rank two transmissions, two layers of elements (e.g., TB1, TB2, CE1, CE2, IM1, IM2, SS1, and/or SS2) of FIG. **4** may be used; with rank three transmissions, three layers of elements (e.g., TB1, TB2, TB3, CE1, CE2, CE3, IM1, IM2, IM3, SS1, SS2, and/or SS3) of FIG. **4** may be used; and with rank four transmissions, four layers of elements (e.g., TB1, TB2, TB3, TB4, CE1, CE2, CE3, CE4, IM1, IM2, IM3, and IM4, SS1, SS2, SS3, and/or SS4) of FIG. **4** may be used.

In embodiments of FIG. **4**, base station processor **101** may support two HARQ process/codeword MIMO with 4 channel encoders CE1-CE4. Using feedback from wireless terminal **200** (indicated by "feedback channel"), adaptive controller **415** chooses transport block length, modulation order, and coding rate (used by transport block generator **401**, encoder **403**, and/or modulator **405**). Adaptive controller **415** also generates precoding weight information used by layer precoder **411**. Even though encoder **403** includes four channel encoders CE1-CE4, wireless terminal **200** may only provide feedback information for a maximum of two encoded transport block codewords. Stated in other words, wireless terminal **200** may provide one HARQ process/codeword for rank one transmissions (with one transport data blocks per TFRE using one downlink data streams), wireless terminal **200** may provide two HARQ processes/codewords for rank two transmissions (with two transport data blocks per TFRE using two

downlink data streams), wireless terminal **200** may provide two HARQ processes/codewords for rank three transmissions (with three transport data blocks per TFRE using three downlink data streams), and wireless terminal **200** may provide two HARQ processes/codewords for rank four transmissions (with four transport data blocks per TFRE using four downlink data streams).

For rank three and rank four transmissions, a number of data streams generated by transport block generator **401**, encoder **403**, modulator **405**, and spreader scrambler **409** is greater than a number of HARQ processes/codewords supported by base station **100** and/or wireless terminal **200**. According to embodiments of present inventive concepts discussed herein, a HARQ process/codeword may be mapped to more than one data stream for rank **3** and rank **4** transmissions. For rank one transmissions, one HARQ process/codeword may be mapped directly to a first data stream (e.g., transmitted using a first transmission layer including TB**1**, CE**1**, IM**1**, and/or SS**1** and received using a first reception layer including DM**1**, SB**1**, and/or CD**1**). For rank two transmission, a first HARQ process/codeword may be mapped directly to a first data stream (e.g., transmitted using a first transmission layer including TB**1**, CE**1**, IM**1**, and/or SS**1** and received using a first reception layer including DM**1**, SB**1**, and/or CD**1**), and a second HARQ process/codeword may be mapped directly to a second data stream (e.g. transmitted using a third transmission layer including TB**3**, CE**3**, IM**3**, and/or SS**3** and received using a third reception layer including DM**3**, SB**3**, and/or CD**3**). For rank three transmission, a first HARQ process/codeword may be mapped to a first data stream (e.g., transmitted using a first transmission layer including TB**1**, CE**1**, IM**1**, and/or SS**1** and received using a first reception layer including DM**1**, SB**1**, and/or CD**1**) and to a second data stream (e.g. transmitted using a second transmission layer including TB**2**, CE**2**, IM**2**, and/or SS**2** and received using a second reception layer including DM**2**, SB**2**, and/or CD**2**), and a second HARQ process/codeword may be mapped to a third data stream (e.g., transmitted using a third transmission layer including TB**3**, CE**3**, IM**3**, and/or SS**3** and received using a third reception layer including DM**3**, SB**3**, and/or CD**3**). For rank four transmission, a first HARQ process/codeword may be mapped to a first data stream (e.g., transmitted using a first transmission layer including TB**1**, CE**1**, IM**1**, and/or SS**1** and received using a first reception layer including DM**1**, SB**1**, and/or CD**1**) and to a second data stream (e.g., transmitted using a second transmission layer including TB**2**, CE**2**, IM**2**, and/or SS**2** and received using a second reception layer including DM**2**, SB**2**, and/or CD**2**), and a second HARQ process/codeword may be mapped to a third data stream (e.g. transmitted using a third transmission layer including TB**3**, CE**3**, IM**3**, and/or SS**3** and received using a third reception layer including DM**3**, SB**3**, and/or CD**3**) and to a fourth data stream (e.g., transmitted using a fourth transmission layer including TB**4**, CE**4**, IM**4**, and/or SS**4** and received using a fourth reception layer including DM**4**, SB**4**, and/or CD**4**).

According to some other embodiments, For rank one transmissions, one HARQ process/codeword may be mapped directly to a first data stream (e.g., transmitted using a first transmission layer including TB**1**, CE**1**, IM**1**, and/or SS**1** and received using a first reception layer including DM**1**, SB**1**, and/or CD**1**). For rank two transmission, a first HARQ process/codeword may be mapped directly to a first data stream (e.g., transmitted using a first transmission layer including TB**1**, CE**1**, IM**1**, and/or SS**1** and received using a first reception layer including DM**1**, SB**1**, and/or CD**1**), and a second HARQ process/codeword may be mapped directly to a second data stream (e.g., transmitted using a third transmission layer including TB**2**, CE**2**, IM**2**, and/or SS**2** and received using a third reception layer including DM**2**, SB**2**, and/or CD**2**). For rank three transmission, a first HARQ process/codeword may be mapped to a first data stream (e.g., transmitted using a first transmission layer including TB**1**, CE**1**, IM**1**, and/or SS**1** and received using a first reception layer including DM**1**, SB**1**, and/or CD**1**), and a second HARQ process/codeword may be mapped to a second data stream (e.g., transmitted using a second transmission layer including TB**2**, CE**2**, IM**2**, and/or SS**2** and received using a second reception layer including DM**2**, SB**2**, and/or CD**2**) and to a third data stream (e.g., transmitted using a third transmission layer including TB**3**, CE**3**, IM**3**, and/or SS**3** and received using a third reception layer including DM**3**, SB**3**, and/or CD**3**). For rank four transmission, a first HARQ process/codeword may be mapped to a first data stream (e.g., transmitted using a first transmission layer including TB**1**, CE**1**, IM**1**, and/or SS**1** and received using a first reception layer including DM**1**, SB**1**, and/or CD**1**) and to a fourth data stream (e.g., transmitted using a fourth transmission layer including TB**4**, CE**4**, IM**4**, and/or SS**4** and received using a fourth reception layer including DM**4**, SB**4**, and/or CD**4**), and a second HARQ process/codeword may be mapped to a second data stream (e.g., transmitted using a second transmission layer including TB**2**, CE**2**, IM**2**, and/or SS**2** and received using a second reception layer including DM**2**, SB**2**, and/or CD**2**) and to a third data stream (e.g., transmitted using a third transmission layer including TB**3**. CE**3**, IM**3**, and/or SS**3** and received using a third reception layer including DM**3**, SB**3**, and/or CD**3**).

Based on the rank chosen by adaptive controller **415**, transport data blocks may be passed to encoder **403**, and encoder outputs may be interleaved and modulated using modulator **405**. Outputs of modulator **405** may be mapped to space time layers using layer mapper **407**, and as discussed above, layer mapper **407** may provide a one-to-one layer mapping. The symbol stream(s) generated by layer mapper **407** may be spread and scrambled using spreader/scrambler **409**, and layer precoder **411** may precode outputs of spreader/scrambler **409**, with precoder outputs being passed through transceiver **109** and antenna array **117** (including Antennas Ant-**1**, Ant-**2**, Ant-**3**, and Ant-**4**).

At wireless terminal **200** operations of processor **201** may mirror operations of base station processor **101** when receiving the MIMO downlink communications transmitted by the base station. More particularly, elements/functionalities of wireless terminal processor **201** are illustrated in FIG. **5** mirroring elements/functionalities of base station processor **101** discussed above with reference to FIG. **4**.

Radio signals may be received through MIMO antenna elements of MIMO antenna array **217** and transceiver **209**, and the radio signals may be decoded by layer decoder **601** using a MIMO decoding vector to generate a plurality of MIMO decoded symbol layers X**1'**, X**2'**, X**3'**, and/or X**4'** depending on MIMO rank used for transmission/reception. Layer Decoder **601** may use a decoding vector corresponding to the precoding vector used by base station **100**. Layer decoder **601** may generate a single decoded symbol layer X**1'** for rank **1** reception, layer decoder **601** may generate two decoded symbol layers X**1'** and X**3'** for rank **2** reception, layer decoder **601** may generate three decoded symbol layers X**1'**, X**2'**, and X**3'** for rank **3** reception, and layer decoder **601** may generate four decoded symbol layers X**1'**, X**2'**, X**3'**, and X**4'** for rank **4** transmission. Layer decoder **601** may thus perform a converse of operations performed by layer precoder **411** and spreader/scrambler **409** of base station **100**. Layer decoder

601 may perform functionalities of a MIMO detector (corresponding to a converse of layer precoder 411) and of dispreading/descrambling blocks for each data stream/layer (corresponding to a converse of spreader/scrambler 409). Layer demapper 603 may function as a converse of layer mapper 407 to demap decoded symbol layers X1', X2', X3', and/or X4' to respective unmapped symbol layers D1', D2', D3', and/or D4' according to the transmission rank.

For rank one reception, layer demapper 603 may demap symbols of decoded symbol layer X1' blocks x1'-j directly to symbols of unmapped symbol layer D1' blocks d1'-j, demodulator/deinterleaver DM-1 may demodulate/deinterleave unmapped symbol layer blocks d1'-j to provide data codewords cw1'-j of data codeword stream CW1', and channel decoder CD1 may decode data codewords cw1'-j of data codeword stream CW1' to provide transport blocks b1'-j of stream B1'. Transport block generator 607 may then pass transport blocks b1'-j of stream B1' as a data stream. During rank one reception, demodulators/deinterleavers DM2, DM3, and DM4 and channel decoders CD2, CD3, and CD4 may be unused.

For rank two reception, layer decoder 601 may generate decoded symbol layers X1' and X3'. Layer demapper 603 may demap symbols of decoded symbol layer X1'blocks x1'-j directly to symbols of unmapped symbol layer D1' blocks d1'-j, and layer demapper 603 may demap symbols of decoded symbol layer X3' blocks x3'-j directly to symbols of unmapped symbol layer D3' blocks d3'-j. Demodulator/deinterleaver DM-1 may demodulate/deinterleave unmapped symbol layer blocks d1'-j to provide data codewords cw1'-j of data codeword stream CW1', and demodulator/deinterleaver DM-3 may demodulate/deinterleave unmapped symbol layer blocks d3'-j to provide data codewords cw3'-j of data codeword stream CW3'. Channel decoder CD1 may decode data codewords cw1'-j of data codeword stream CW1' to provide transport blocks b1'-j of stream B1', and channel decoder CD3 may decode data codewords cw3'-j of data codeword stream CW3' to provide transport blocks b3'-j of stream B3'. Transport block generator 607 may then combine transport blocks b1'-j and b3'-j of streams B1' and B3' as a data stream. During rank two reception, demodulators/deinterleavers DM2 and DM4 and channel decoders CD2 and CD4 may be unused.

For rank three reception, layer decoder 601 may generate decoded symbol layers X1', X2', and X3'. Layer demapper 603 may demap symbols of decoded symbol layer X1' blocks x1'-j directly to symbols of unmapped symbol layer D1' blocks d1'-j, layer demapper 603 may demap symbols of decoded symbol layer X2' blocks x2'-j directly to symbols of unmapped symbol layer D2' blocks d2'-j, and layer demapper 603 may demap symbols of decoded symbol layer X3' blocks x3'-j directly to symbols of unmapped symbol layer D3' blocks d3'-j. Demodulator/deinterleaver DM-1 may demodulate/deinterleave unmapped symbol layer blocks d1'-j to provide data codewords cw1'-j of data codeword stream CW1', demodulator/deinterleaver DM-2 may demodulate/deinterleave unmapped symbol layer blocks d2'-j to provide data codewords cw2'-j of data codeword stream CW2', and demodulator/deinterleaver DM-3 may demodulate/deinterleave unmapped symbol layer blocks d3'-j to provide data codewords cw3'-j of data codeword stream CW3'. Channel decoder CD1 may decode data codewords cw1'-j of data codeword stream CW1' to provide transport blocks b1'-j of stream B1', channel decoder CD2 may decode data codewords cw2'-j of data codeword stream CW2' to provide transport blocks b2'-j of stream B2', and channel decoder CD3 may decode data codewords cw3'-j of data codeword stream CW3' to provide transport blocks b3'-j of stream B3'. Transport block generator 607 may then combine transport blocks b1'-j, b2'-j, and b3'-j of streams B1', B2', and B3' as a data stream. During rank three reception, demodulator/deinterleaver DM4 and channel decoder CD4 may be unused.

For rank four reception, layer decoder 601 may generate decoded symbol layers X1', X2', X3', X4'. Layer demapper 603 may demap symbols of decoded symbol layer X1' blocks x1'-j directly to symbols of unmapped symbol layer D1' blocks d1'-j, layer demapper 603 may demap symbols of decoded symbol layer X2' blocks x2'-j directly to symbols of unmapped symbol layer D2' blocks d2'-j, and layer demapper 603 may demap symbols of decoded symbol layer X3' blocks x3'-j directly to symbols of unmapped symbol layer D3' blocks d3'-j, and layer demapper 603 may demap symbols of decoded symbol layer X4' blocks x4'-j directly to symbols of unmapped symbol layer D4' blocks d4'-j. Demodulator/deinterleaver DM-1 may demodulate/deinterleave unmapped symbol layer blocks d1'-j to provide data codewords cw1'-j of data codeword stream CW1', demodulator/deinterleaver DM-2 may demodulate/deinterleave unmapped symbol layer blocks d2'-j to provide data codewords cw2'-j of data codeword stream CW2', demodulator/deinterleaver DM-3 may demodulate/deinterleave unmapped symbol layer blocks d3'-j to provide data codewords cw3'-j of data codeword stream CW3', and demodulator/deinterleaver DM-4 may demodulate/deinterleave unmapped symbol layer blocks d4'-j to provide data codewords cw4'-j of data codeword stream CW4'. Channel decoder CD1 may decode data codewords cw1'-j of data codeword stream CW1' to provide transport blocks b1'-j of stream B1', channel decoder CD2 may decode data codewords cw2'-j of data codeword stream CW2' to provide transport blocks b2'-j of stream B2', channel decoder CD3 may decode data codewords cw3'-j of data codeword stream CW3' to provide transport blocks b3'-j of stream B3', and channel decoder CD4 may decode data codewords cw4'-j of data codeword stream CW4' to provide transport blocks b4'-j of stream B4'. Transport block generator 607 may then combine transport blocks b1'-j, b2'-j, b3'-j and b4'-j of streams B1', B2'. B3', and B4' as a data stream.

As further shown in FIG. 5, a respective soft buffer SB1, SB2, SB3, and SB4 may be provided for each stream of received data, and each decoder CD1, CD2, CD3, and CD4 may be configured to determine whether each decoded transport data block passes or fails decoding. In greater detail, each undecoded transport data block generated by a demodulator/decoder DM may be saved in the respective soft buffer SB until a decoding result is determined by the channel decoder CD. If the transport data block passes decoding, an ACK (acknowledge message) may be generated and provided as feedback for the base station, and retransmission of the successfully decoded (passed) data block is not required. If the transport data block does not pass decoding, a NACK (negative acknowledge message) may be generated and provided as feedback for the base station, and the undecoded output of the demodulator/deinterleaver (also referred to as soft bits) may be saved in soft buffer SB. Responsive to the NACK, the base station may retransmit the failed transport data block, and wireless terminal 200 may use the retransmitted data block together with the previously undecoded output of the demodulator/deinterleaver (that is saved in the respective soft buffer) to decode the retransmitted data block on the second pass. By using the soft buffer to combine first and second versions of the demodulated data block, a likelihood of successful decoding may be increased after retransmission.

As shown in FIG. 5, layer decoder 601 (e.g., including a MIMO detector such as a minimum mean squared error or

MMSE receiver), may reduce interference from the multipath channel and/or may reduce other antenna interference. After dispreading, demapping, demodulating, and/or deinterleaving, wireless terminal **200** may attempt to decode the coded bits of a transport data block using a respective channel decoder. If the decoding attempt fails, wireless terminal **200** buffers the received soft bits of the transport data block in the respective soft buffer, and requests retransmission of the transport data block by transmitting a NACK message (e.g., as a part of an HARQ-ACK codeword, also referred to as a HARQ codeword). Once the retransmission is received (and subjected to decoding, demapping, demodulating, and/or deinterleaving) by wireless terminal **200**, wireless terminal may combine the buffered soft bits with the received soft bits from the retransmission and attempt to decode the combination using a respective channel decoder.

For soft combining to operate properly, the wireless terminal may need to know whether a received transmission is a new transmission of a transport data block or a retransmission of a previously transmitted transport data block. For this purpose, the downlink control signaling may include a data indicator (also referred to as an indicator, a new data indicator, a data indicator, etc.) that is used by the wireless terminal to control whether the soft buffer should be cleared or whether soft combining of the soft buffer and the received soft bits should take place. For a given transmission/retransmission to wireless terminal **200**, the data indicator may thus have one value to indicate an initial transmission of new data and another value to indicate a retransmission of previously transmitted data.

Whenever a current transmission is not a retransmission, a NodeB base station MAC-ehs element of base station processor **101** may increment a single bit data indicator. Accordingly, the single bit data indicator may be toggled each time a new transport data block is transmitted over a MIMO layer. The data indicator can thus be used by wireless terminal processor **201** to clear the soft buffer/buffers for each initial transmission because no soft combining should be done for new/initial transmissions. The indicator may also be used to detect error cases in the status signaling. If the data indicator is not toggled despite the fact that the previous data for the HARQ process in question was correctly decoded and acknowledged (using an ACK message), for example, an error in the uplink signaling has most likely occurred. Similarly, if the indicator is toggled but the previous data for the HARQ process was not correctly decoded, the wireless terminal may replace the data previously in the soft buffer for the HARQ process with the new received data.

For rank four transmissions, wireless terminal **200** may thus receive up to four transport data blocks in a same TFRE to support four streams of transport data blocks. After decoding four data blocks for a TFRE during a rank **4** transmission, each decoder CD**1**, CD**2**, CD**3**, and CD**4** may generate a respective local ACK or NACK depending on whether the respective transport data block passed or failed decoding. In a rank **4** transmission, decoders CD**1** and CD**2** may be mapped to the first HARQ process so that the resulting HARQ ACK/NACK is an ACK only if both decoders CD**1** and CD**2** generate a local ACK and the resulting HARQ AKC/NACK message from the first HARQ process is a NACK if either decoder CD**1** or CD**2** generated a local NACK; and decoders CD**3** and CD**4** may be mapped to the second HARQ process so that the resulting HARQ ACK/NACK from the second HARQ process is an ACK only if both decoders CD**3** and CD**4** generate a local ACK and the resulting HARQ AKC/NACK message is a NACK if either decoder CD**3** or CD**4** generated a local NACK.

For rank three transmissions, wireless terminal **200** may thus receive up to three transport data blocks in a same TFRE. After decoding three data blocks for a TFRE during a rank **3** transmission, each decoder CD**1**, CD**2**, and CD**3** may generate a respective local ACK or NACK depending on whether the respective transport data block passed or failed decoding. In a rank **3** transmission, decoders CD**1** and CD**2** may be mapped to the first HARQ process so that the resulting HARQ ACK/NACK is an ACK only if both decoders CD**1** and CD**2** generate a local ACK and the resulting HARQ AKC/NACK message from the first HARQ process is a NACK if either decoder CD**1** or CD**2** generated a local NACK; and decoder CD**3** may be mapped to the second HARQ process so that the resulting HARQ ACK/NACK from the second HARQ process is an ACK if decoder CD**3** generates a local ACK and the resulting HARQ AKC/NACK message is a NACK if decoder CD**3** generates a local NACK.

For rank two transmissions, wireless terminal **200** may receive up to two transport data blocks in a same TFRE. After decoding two data blocks for a TFRE during a rank **2** transmission, each decoder CD**1** and CD**3** may generate a respective local ACK or NACK depending on whether the respective transport data block passed or failed decoding. In a rank two transmission, decoder CD**1** may be mapped to the first HARQ process so that the resulting HARQ ACK/NACK is an ACK only if decoder CD**1** generates a local ACK and the resulting HARQ AKC/NACK message from the first HARQ process is a NACK if decoder CD generates a local NACK; and decoder CD**3** may be mapped to the second HARQ process so that the resulting HARQ ACK/NACK from the second HARQ process is an ACK if decoder CD**3** generates a local ACK and the resulting HARQ AKC/NACK message is a NACK if decoder CD**3** generates a local NACK.

For rank one transmissions, wireless terminal **200** may thus receive one transport data block in a TFRE. After decoding one data block for a TFRE during a rank **1** transmission, decoder CD**1** may generate a respective local ACK or NACK depending on whether the transport data block passed or failed decoding. In a rank one transmission, decoder CD**1** may be mapped to the first HARQ process so that the resulting HARQ ACK/NACK is an ACK if decoder CD**1** generates a local ACK and the resulting HARQ AKC/NACK message from the first HARQ process is a NACK if decoder CD**1** generates a local NACK.

According to some other embodiments, first transmission/reception layers TL**1**/RL**1** may be used during rank **1** transmission/reception, and HARQ process HARQ-**1** may be mapped to a data block of the first transmission/reception layers TL**1**/RL**1** during rank **1** transmission/reception. First and second transmission/reception layers TL**1**/RL**1** and TL**2**/RL**2** may be used during rank **2** transmission/reception, HARQ process HARQ-**1** may be mapped to a data block of the first transmission/reception layers TL**1**/RL**1** during rank **1** transmission/reception, and HARQ process HARQ-**2** may be mapped to a data block of the second transmission/reception layers TL**2**/RL**2** during rank **2** transmission/reception. First, second, and third transmission/reception layers TL**1**/RL**1**, TL**2**/RL**2**, and TL**3**/RL**3** may be used during rank **3** transmission/reception, HARQ process HARQ-**1** may be mapped to a data block of the first transmission/reception layers TL**1**/RL**1** during rank **3** transmission/reception, and HARQ process HARQ-**2** may be mapped to data blocks of the second and third transmission/reception layers TL**2**/RL**2** and TL**3**/RL**3** during rank **3** transmission/reception. First, second, third, and fourth transmission/reception layers TL**1**/RL**1**, TL**2**/RL**2**, TL**3**/RL**3**, and TL**4**/RL**4** may be used during rank **4** transmission/reception, HARQ process HARQ-**1** may be mapped to

data blocks of the first and fourth transmission/reception layers TL1/RL1 and TL4/RL4 during rank 4 transmission/reception, and HARQ process HARQ-2 may be mapped to data blocks of the second and third transmission/reception layers TL2/RL2 and TL3/RL3 during rank 4 transmission/reception.

According to embodiments of present inventive concepts, a HARQ process in a MAC-ehs of wireless terminal processor **101** may provide MAC functionality illustrated in FIG. **6**. FIG. **6** illustrates MAC (Media Access Control) functionality at wireless terminal **200**. As shown in FIG. **6** one HARQ entity may handle HARQ functionality for one user per HS-DSCH (High Speed Downlink Shared Channel). One HARQ entity may be capable of supporting multiple instances (multiple HARQ processes) of stop and wait HARQ protocols. According to some embodiments, there shall be one HARQ entity per HS-DSCH, one HARQ process per TTI (Transmission Time Interval) for single stream (rank one) transmission, and two HARQ processes per TTI for two stream (rank two) transmission, three stream (rank three) transmission, and four stream (rank four) transmission.

Because only 2 HARQ processes are supported for MIMO transmission/reception using three downlink streams (rank three) and for MIMO transmission/reception using four downlink streams (rank four), the mapping of soft buffers may be provided according to the table of FIG. **7**A for rank **3** downlink transmission/reception and according to the table of FIG. **7**B for rank **4** downlink transmission/reception. Note that any one of the combinations of FIG. **7**A may be used for rank **4** downlink transmission, and that any one of the combinations of FIG. **7**B may be used for rank **3** down link transmissions. Whenever the data indicator for a shared HARQ process (i.e. a HARQ process shared by two or more streams/layers) indicates that new data has been initially transmitted over the downlink (e.g. the data indicator bit has been toggled), the soft buffers for both/all streams associated with the shared HARQ process should be cleared. Whenever the data indicator for a shared HARQ process (i.e., a HARQ process shared by two or more streams/layers) indicates that old data is being retransmitted, the soft buffers for both/all streams associated with the shared HARQ process should be combined with the retransmitted data of the respective data streams.

For rank one transmissions, a first HARQ process may be used for the single downlink data stream (e.g., for a downlink stream transmitted using TB**1**, CE**1**, IM**1**, and/or SS**1** defining a first transmission layer and received using DM**1**, SB**1**, and/or CD**1** defining a first reception layer). Accordingly, one data indicator flag may be transmitted by base station for one transport data block of the downlink data stream, and wireless terminal **200** may receive the one transport data block using DM**1**, SB**1**, and CD**1**. If the data indicator indicates that the transport data block is a new/initial transmission, wireless terminal **200** may clear soft buffer SB**1** and attempt to decode using channel decoder CD**1**. If the data indicator indicates that the transport data block is a retransmission of a previously failed transmission, wireless terminal **200** may combine soft bits of the retransmission (generated by demodulator/deinterleaver DM**1**) with soft bits from soft buffer SB**1** and attempt to decode the combination using channel decoder CD**1**. If channel decoder CD**1** is able to successfully decode the transmission/retransmission, an ACK message is generated and transmitted to base station **100** (e.g., as an element of a HARQ-ACK codeword, also referred to as a HARQ codeword). If channel decoder CD**1** is unable to decode the transmission/retransmission, a NACK message is generated and transmitted to base station **100** (e.g., as an element of a HARQ-ACK codeword, also referred to as a HARQ codeword). A single HARQ process (including a data indicator, a NACK message and/or an ACK message) may thus map to each transport data block transmitted over the rank/layer one downlink data stream.

For rank two transmissions, a first HARQ process (including a data indicator, a NACK message and/or an ACK message) may map to each transport data block transmitted over a first stream of the rank two transmission (e.g., for a downlink stream transmitted using TB**1**, CE**1**, IM**1**, and/or SS**1** defining a first transmission layer and received using DM**1**, SB**1**, and/or CD**1** defining a first reception layer), and a second HARQ process (including a data indicator, a NACK message and/or an ACK message) may map to each transport data block transmitted over a second stream of the rank two transmission (e.g., for a downlink stream transmitted using TB**3**, CE**3**, IM**3**, and/or SS**3** defining a third transmission layer and received using DM**3**, SB**3**, and/or CD**3** defining a third reception layer). Each of the first and second HARQ processes may thus operate for transport data blocks of respective streams of the rank two transmissions as discussed above with respect to rank/layer one transmissions. Stated in other words, a respective data indicator may be provided for each transport data block received during a same TFRE, soft buffers for the respective downlink data streams may be independently cleared or maintained for retransmission combining responsive to the respective data indicators, and respective ACK/NACK messages may be generated and transmitted to base station **100** for each transport data block received during a same TFRE.

For higher order transmission ranks/layers, however, a HARQ process may be shared by two or more downlink data streams to reduce uplink feedback signaling. For rank three downlink transmissions, a first HARQ process (including one data indicator and one ACK/NACK message per TFRE) may map to first and second streams of transport data blocks, and a second HARQ process (including one data indicator and one ACK/NACK message per TFRE) may map to a third stream of transport data blocks. For rank three downlink transmissions, for example, a first HARQ process may map to each transport data block transmitted over a first stream of the rank three transmission (e.g., for a downlink stream transmitted using TB**1**, CE**1**, IM**1**, and/or SS**1** defining a first transmission layer and received using DM**1**, SB**1**, and/or CD**1** defining a first reception layer) and to each transport data block transmitted over a second stream of the rank three transmission (e.g., for a downlink stream transmitted using TB**2**, CE**2**, IM**2**, and/or SS**2** defining a second transmission layer and received using DM**2**, SB**2**, and/or CD**2** defining a second reception layer); and a second HARQ process may map to each transport data block transmitted over a third stream of the rank three transmission (e.g., for a downlink stream transmitted using TB**3**, CE**3**, IM**3**, and/or SS**3** defining a third transmission layer and received using DM**3**, SB**3**, and/or CD**3** defining a third reception layer). During rank three transmissions, the first HARQ process may thus be shared by data blocks of the first and second streams that are transmitted using a same TFRE so that the first and second streams are bundled to a same HARQ process. Accordingly, one HARQ ACK/NACK message and one data indicator may be mapped to both data blocks of a same TFRE for the first and second streams during rank three transmission. In contrast, the second HARQ process, may be applied to only the third data stream, so that one HARQ ANK/NACK message and one data indicator may be mapped to one data block of each TFRE of the third stream.

Accordingly, first, second, and third transport data blocks may be transmitted during a same TFRE over respective the first, second, and third streams during a rank three transmission. A first data indicator may be transmitted by base station **100** for both of the first and second transport data blocks of the first and second downlink data streams. If the first data indicator indicates a new/initial transmission, wireless terminal **200** may clear soft buffers SB**1** and SB**2** and attempt to decode the first and second transport data blocks using channel decoders CD**1** and CD**2**. If the first data indicator indicates a retransmission, wireless terminal **200** may combine soft bits of the first and second transport data blocks (generated by demodulators/deinterleavers DM**1** and DM**2**) with soft bits from respective soft buffers SB**1** and SB**2** and attempt to decode the combinations using respective channel decoders CD**1** and CD**2**. If both channel decoders CD**1** and CD**2** are able to successfully decode the transmissions/retransmissions, an ACK message is generated and transmitted to base station **100** (e.g., as an element of a shared HARQ-ACK codeword, also referred to as a shared HARQ codeword). If either of channel decoders CD**1** or CD**2** is unable to decode the transmissions/retransmissions, a NACK message is generated and transmitted to base station **100** (e.g., as an element of a shared HARQ-ACK codeword, also referred to as a shared HARQ codeword). The first HARQ process (including a single data indicator and a single ACK/NACK message) may thus be shared by two transport data blocks transmitted over different downlink data streams during a same TFRE. A second data indicator may be transmitted by base station **100** for the third transport data block of the third stream, and soft buffer SB**3** may be cleared if the second data indicator indicates that the third transport data block is an initial transmission, or soft buffer SB**3** may be maintained for combined decoding if the second data indicator indicates that the first transport data block is a retransmission. If channel decoder CD**3** is able to successfully decode the transmission/retransmission, an ACK message is generated and transmitted to base station **100** (e.g., as an element of a HARQ-ACK codeword, also referred to as a HARQ codeword). If channel decoder CD**3** is unable to decode the transmissions/retransmissions, a NACK message is generated and transmitted to base station **100** (e.g. as an element of a HARQ-ACK codeword, also referred to as a HARQ codeword).

For rank/layer four downlink transmissions according to some embodiments, the first HARQ process may be shared between a first stream (e.g., for a downlink stream transmitted using TB**1**, CE**1**, IM**1**, and/or SS**1** defining a first transmission layer and received using DM**1**, SB**1**, and/or CD**1** defining a first reception layer) and a second stream (e.g. for a downlink stream transmitted using TB**2**, CE**2**, IM**2**, and/or SS**2** defining a second transmission layer and received using DM**2**, SB**2**, and/or CD**2** defining a second reception layer), and the second HARQ process may be shared between a third stream (e.g., for a downlink stream transmitted using TB**3**, CE**3**, IM**3**, and/or SS**3** defining a third transmission layer and received using DM**3**, SB**3**, and/or CD**3** defining a third reception layer) and a fourth stream (e.g., for a downlink stream transmitted using TB**4**, CE**4**, IM**4**, and/or SS**4** defining a fourth transmission layer and received using DM**4**, SB**4**, and/or CD**4** defining a fourth reception layer). The sharing of a HARQ process between any two data streams may be the same as discussed above with respect the sharing of the first HARQ process between first and second data streams during rank three transmissions. Where a HARQ process is shared between two streams, the HARQ process provides one data indicator and one ACK/NACK message for each TFRE for all data streams sharing the HARQ process. Operations of a HARQ process shared by multiple data streams will now be discussed in greater detail below with respect to the flow charts of FIGS. **8**A and **8**B.

FIG. **8**A illustrates operations of a base station transmitting multiple MIMO data streams using a shared HARQ process according to some embodiments of present inventive concepts, and FIG. **8**B illustrates operations of a wireless terminal receiving multiple MIMO data streams using a shared HARQ process according to some embodiments of present inventive concepts. Operations of FIGS. **8**A and **8**B may be discussed concurrently because the base station and wireless terminal operations may be interleaved.

As shown in FIG. **8**A, base station processor **101** may determine for an HARQ process if the HARQ process is being applied to a single MIMO data stream or if the HARQ process is being shared by multiple (e.g., two) MIMO data streams at block **811**. If the HARQ process is being applied to only one MIMO data stream, the HARQ process may be applied individually to the single MIMO data stream at block **815** so that one ACK/NACK message (received from wireless terminal **200**) from the prior TFRE is applied only to the single MIMO data stream for the current TFRE, and so that one data indicator is applied only to the single MIMO data stream for the current TFRE.

If the HARQ process is being shared by multiple MIMO data streams at block **811**, base station processor **101**, may determine whether an ACK message or a NACK message was received in response to transport data blocks transmitted over the multiple MIMO data streams in a/the preceding TFRE. As discussed above, one ACK or NACK message may be transmitted by wireless terminal **200** for a plurality data streams sharing a HARQ process.

If an ACK message was received for the prior TFRE transmission at block **817**, base station processor **101** may generate and transmit a data indicator indicating an initial transmission of new data for all transport data blocks being transmitted during the current TFRE for the data streams sharing the HARQ process at block **819**. At block **821**, base station processor **101** may generate and transmit new transport data blocks for all data streams sharing the HARQ process.

If a NACK message was received for the prior TFRE transmission at block **817**, base station processor **101** may generate and transmit a data indicator indicating a retransmission of the prior data for all transport data blocks being transmitted during the current TFRE for the data streams sharing the HARQ process at block **831**. At block **833**, base station processor **101** may retransmit the previously transmitted transport data blocks for all data streams sharing the HARQ process. A single NACK message may thus result in retransmission of transport data blocks for all data streams sharing the HARQ process.

As shown in FIG. **8**B responsive to receiving data for a TFRE at block **849**, wireless terminal processor **201** may determine for a HARQ process if the HARQ process is being applied to a single MIMO data stream or if the HARQ process is being shared by multiple (e.g., two) MIMO data streams at block **851**. If the HARQ process is being applied to only one MIMO data stream, the HARQ process may be applied individually to the single MIMO data stream at block **853** so that one ACK/NACK message is generated for only the single MIMO data stream, and so that a data indicator is applied only to the single MIMO data stream for the current TFRE. As discussed above with respect to a four antenna system, for example, a first HARQ process (HARQ-**1**) may be applied individually to a first MIMO data stream (e.g., using TB**1**, CE**1**, IM**1**, DM**1**, SB**1**, and/or CD**1**) for rank **1**, rank **2**, and

rank 3 transmission/reception, and a second HARQ process (HARQ-2) may be applied individually to a second MIMO data stream (e.g., using TB2, CE2, IM2, DM2, SB2, and/or CD2) for rank 2 transmission/reception.

If the HARQ process is being shared by multiple MIMO data streams at block **851**, wireless terminal processor **201** may determine at block **855** whether a data indicator (transmitted by base station **100**) indicates that the transport data blocks are initial transmissions of new data or retransmissions of old data transmitted in a previous TFRE. As discussed above with respect to a four antenna system, for example, a first HARQ process (HARQ-1) may be shared by a first MIMO data stream (e.g., using TB1, CE1, IM1, DM1, SB1, and/or CD1) and a fourth MIMO data stream (e.g., using TB4, CE4, IM4, DM4, SB4, and/or CD4) for rank 4 transmission/reception, and a second HARQ process (HARQ-2) may be shared by a second MIMO data stream (e.g., using TB2, CE2, IM2, DM2, SB2, and/or CD2) and a third MIMO data stream (e.g., using TB3, CE3, IM3, DM3, SB3, and/or CD3) for rank 3 and rank 4 transmission/reception.

If the transport data blocks of the shared HARQ process are initial transmissions of new data, all soft buffers of the data streams sharing the HAQ process are cleared at block **861** (responsive to the one data indicator), and each of the transport data blocks of the data streams sharing the HARQ process are separately demodulated at block **863** to generate soft bits for the respective transport data blocks. The soft bits for the respective transport data blocks are then decoded at bock **865** to generate the original transport data blocks. If all of the current transport data blocks (of the current TFRE) of the MIMO data streams sharing the HARQ process are successfully decoded at block **867**, one ACK message may be generated and transmitted to base station **100** at block **869** for all of the transport data blocks sharing the HARQ process. If one of the current transport data blocks (of the current TFRE) of the MIMO data streams sharing the HARQ process fails decoding at block **867**, one NACK message may be generated and transmitted to base station **100** at block **871** for all of the transport data blocks sharing the HARQ process.

If the transport data blocks of the shared HARQ process are retransmissions at block **855**, all soft buffers of the data streams sharing the HAQ process are maintained at block **881** (responsive to the one data indicator indicating retransmission), and each of the transport data blocks of the data streams sharing the HARQ process are separately demodulated at block **883** to generate soft bits for the respective transport data blocks. The soft bits for the respective transport data blocks are then combined with the corresponding soft bits from respective soft buffers at block **885**, and the combinations of old/new soft bits are separately decoded at bock **887** to generate the original transport data blocks. If all of the current transport data blocks (of the current TFRE) of the MIMO data streams sharing the HARQ process are successfully decoded at block **887** and **867**, one ACK message may be generated and transmitted to base station **100** at block **869** for all of the transport data blocks sharing the HARQ process. If one of the current transport data blocks (of the current TFRE) of the MIMO data streams sharing the HARQ process fails decoding at block **867**, one NACK message may be generated and transmitted to base station **100** at block **871** for all of the transport data blocks sharing the HARQ process.

In a multiple HARQ codeword MIMO system supporting up to four MIMO data streams with HARQ codeword dimensioning, for example, two HARQ codewords may be mapped to three MIMO data streams/layers for rank 3 transmissions and to four MIMO data streams/layers for rank 4 transmissions. For rank three downlink transmissions, for example, a first HARQ process (HARQ-1) may map to each transport data block transmitted over a first stream of the rank three transmission (e.g., for a downlink stream transmitted using TB1, CE1, IM1, and/or SS1 defining a first transmission layer TL1 and received using DM1, SB1, and/or CD1 defining a first reception layer RL1) and to each transport data block transmitted over a second stream of the rank three transmission (e.g., for a downlink stream transmitted using TB2, CE2, IM2, and/or SS2 defining a second transmission layer TL2 and received using DM2, SB2, and/or CD2 defining a second reception layer RL2); and a second HARQ process (HARQ-2) may map to each transport data block transmitted over a third stream of the rank three transmission (e.g., for a downlink stream transmitted using TB3, CE3, IM3, and/or SS3 defining a third transmission layer TL3 and received using DM3, SB3, and/or CD3 defining a third reception layer RL3). For rank four downlink transmissions, the first HARQ process (HARQ-1) may map to each transport data block transmitted over a first stream of the rank four transmission (e.g., for a downlink stream transmitted using TB1, CE1, IM1, and/or SS1 defining a first transmission layer TL1 and received using DM1, SB1, and/or CD1 defining a first reception layer RL4) and to each transport data block transmitted over a second stream of the rank four transmission (e.g., for a downlink stream transmitted using TB2, CE2, IM2, and/or SS2 defining a second transmission layer TL2 and received using DM2, SB2, and/or CD2 defining a second reception layer RL2); and the second HARQ process (HARQ-2) may map to each transport data block transmitted over a third stream of the rank four transmission (e.g., for a downlink stream transmitted using TB3, CE3, IM3, and/or SS3 defining a third transmission layer TL3 and received using DM3, SB3, and/or CD3 defining a third reception layer TL4) and over a fourth stream of the rank four transmission (e.g., for a downlink stream transmitted using TB4, CE4, IM4, and/or SS4 defining a fourth transmission layer TL4 and received using DM4, SB4, and/or CD4 defining a fourth reception layer RL4). This sharing of HARQ processes may be referred to as bundling and/or sharing.

As further discussed above, if either data block sharing a HARQ process is not successfully decoded at the respective channel decoder (e.g., if a data block fails at either of channel decoders CD1 or CD2 sharing the first HARQ process (HARQ-1) during a rank 3 or a rank 4 transmission, or if a data block fails at either of channel decoders CD3 or CD4 sharing the second HARQ process (HARQ-2) during a rank 4 transmission, a single NACK for the bundled/shared HARQ process may be transmitted to base station **100** and soft bits for both of the failed data blocks may be saved at respective soft buffers (corresponding to the respective channel decoders and/or HARQ processes) for subsequent combining with retransmissions of the failed data blocks. If the transmission rank requested by wireless terminal **200** changes between transmitting the initial data blocks and retransmitting the failed data blocks, however, the retransmission may be complicated if the updated rank does not support the shared HARQ process for the failed data blocks. More particularly, the soft buffers may be mapped to respective HARQ processes so that the soft bits saved in one or both of the respective soft buffers may be unavailable if the mapping of the bundled HARQ process according to the updated transmission rank does not include both soft buffers. Accordingly, base station **100** may be unable to retransmit the failed bundled data blocks using the updated rank thereby increasing delay in retransmitting the failed bundled data blocks.

In a rank 3 or a rank 4 transmission using one TFRE to transmit three or four data blocks, for example, a first data

block may be transmitted using a first transmission layer TL1 (e.g., including TB1, CE1, IM1, and/or SS1) and received using a first reception layer RL1 (e.g., including DM1, SB1, and/or CD1), and a second data block may be transmitted using a second transmission layer TL2 (e.g., including TB2, CE2, IM2, and/or SS2) and received using a second reception layer RL2 (e.g., including DM2, SB2, and/or CD2). If either or both of the first or second data blocks fails decoding at respective channel decoder CD1 and/or CD2, wireless terminal **200** may transmit a single NACK message to base station **100** indicating failure of the bundled first and second data packets, and soft bits of the first and second data blocks (from respective demodulators/deinterleavers DM1 and DM2) may be saved at respective soft buffers SB1 and SB2 for subsequent combining with retransmissions of the first and second data blocks. If the transmission rank is reduced to rank **1** or rank **2**, however, transmission/reception along the second transmission layer TL2 (e.g. including TB2, CE2, IM2, and/or SS2) and the second reception layer RL2 (e.g., including DM2, SB2, and/or CD2) may no longer be supported so that parallel retransmission of the first and second data packets using the first HARQ process HARQ-1 (including both soft buffers SB1 and SB2) may not be possible.

Similarly, in a rank **4** transmission using one TFRE, for example, a third data block may be transmitted using a third transmission layer TL3 (e.g. including TB3, CE3, IM3, and/or SS3) and received using a third reception layer RL3 (e.g., including DM3, SB3, and/or CD3), and a fourth data block may be transmitted using a fourth transmission layer TL4 (e.g., including TB4, CE4, IM4, and/or SS4) and received using a fourth reception layer RL4 (e.g., including DM4, SB4, and/or CD4). If either or both of the third and/or fourth data blocks fails decoding at respective channel decoder CD3 and/or CD4, wireless terminal **200** may transmit a single NACK message to base station **100** indicating failure of the bundled third and fourth data blocks, and soft bits of the third and fourth data blocks (from respective demodulators/deinterleavers DM3 and DM4) may be saved at respective soft buffers SB3 and SB4 for subsequent combining with retransmissions of the first and second data blocks. If the transmission rank is reduced to rank **1**, rank **2**, or rank **3**, however, transmission/reception along the third and/or fourth transmission/reception layers may no longer be supported so that parallel retransmission of the third and fourth data packets using the second HARQ process HARQ-2 (including both soft buffers SB3 and SB4) may not be possible.

According to some embodiments, base station **100** may delay changing a downlink transmission rank for wireless terminal **200** until either ACKs have been received for all data blocks previously transmitted to wireless terminal **200** or a maximum number of retransmissions have occurred. Accordingly, mappings of HARQ processes to transmission/reception layers (including respective soft buffers) may be maintained as needed for retransmissions of any failed data blocks that were initially transmitted using a shared/bundled HARQ process. Because downlink channel conditions may vary at a relatively low rate over two to three consecutive transmission time intervals, however, a relatively low transmission quality of the downlink channel which resulted in the initial channel decoder failure may remain relatively low so that a higher number of retransmissions may be needed to achieve successful decoding and CRC validation of the failed data block(s). The increased number of retransmissions, however, may increase delay transferring the data block(s) to higher processing layers, and/or an increased residual block error rate may occur.

According to embodiments of present inventive concepts, base station processor **101** may use mapping tables of FIGS. **10-13** to retransmit failed data packets (e.g., associated with a bundled HARQ process) when wireless terminal **200** reports/requests a downlink transmission rank that is different than the downlink transmission rank used to initially transmit the now failed data packets. Embodiments of present inventive concepts are discussed in greater detail below with respect to the tables of FIGS. **10-13** for systems including 4 transmit and 4 receive MIMO antennas supporting one, two, three, and four MIMO transmission ranks. While embodiments relating to 4 transmit and 4 receive MIMO antennas are discussed by way of example, embodiments of present inventive concepts may be applied to systems including fewer and/or more MIMO transmit and receive antennas.

According to some embodiments, base station processor **101** may operate according to a retransmission algorithm such that if a NACK is generated for a bundled HARQ ACK/NACK message for a plurality of data blocks (e.g., for first and second data blocks of a same TFRE transmitted/received using first and second transmission/reception layers including channel decoders CD1 and CD2 during rank **3** and/or rank **4** transmissions, and/or transmitted/received using third and fourth transmission/reception layers including channel decoders CD3 and CD4 during rank **4** transmissions), the bundled data blocks may be retransmitted using a rank selected to maintain a HARQ process mapping for the bundled HARQ NACK message. For example, a base station processor **101** may maintain a rank that is at least as high as that used for the original transmission even if wireless terminal **200** has requested/recommended a lower rank. According to some embodiments, base station processor **101** may maintain a same transmission rank for retransmission of bundled data packets even if wireless terminal **200** has requested/recommended a lower downlink transmission rank to thereby maintain a mapping of the HARQ process (for which the bundled NACK message was received) to the respective transmission and reception layers for both the initial transmission and subsequent retransmission(s).

As shown in FIG. **9**, base station processor **101** may select a downlink (DL) transmission rank for subsequent downlink transmissions to wireless terminal **200** responsive to downlink transmission rank requests and/or recommendations received from wireless terminal **200** over a feedback channel, but base station processor **101** may select a different DL transmission rank if retransmission of any bundled data blocks is required responsive to a HARQ NACK message received for a bundled HARQ process. When a request/recommendation for a new DL transmission rank is received from wireless terminal **200** at block **901**, base station processor **101** may determine at block **903** if retransmission of any bundled data blocks to wireless terminal **200** is required. More particularly, two data blocks may be transmitted using a same TFRE over transmission/reception layers sharing a HARQ process, and if either or both data block(s) fail decoding at wireless terminal **200**, a shared/bundled HARQ NACK message from wireless terminal **200** may request retransmission of the two data blocks.

If no retransmission is required at block **903** (e.g., if all previously transmitted data blocks using shared/bundled HARQ processes have either been acknowledged with ACKs or retransmitted a maximum number of allowed times), base station processor **101** may proceed with the requested and/or recommended DL transmission rank at block **907**. If retransmission of previously transmitted data blocks using a shared/bundled HARQ process(es) is required at block **903**, however, base station processor **101** may select a DL transmission

rank at block **905** to maintain HARQ process mapping for any such retransmissions. DL transmission rank selection of block **905** will be discussed in greater detail below with respect to the mapping tables of FIGS. **10-13**. Once all previously failed bundled data blocks have either been successfully transmitted (as indicated by a HARQ ACK message) or retransmitted a maximum allowed number of times at block **903**, base station processor **101** may then proceed with the requested and/or recommended DL transmission rank at block **907**.

The mapping tables of FIGS. **10-13** illustrate base station processor **101** operations to select transmission rank according to embodiments of present inventive concepts including four transmission/reception layers with two HARQ processes identified as HARQ-**1** and HARQ-**2**. By way of example, first transmission and reception layers TL**1** and RL**1** may be implemented using TB**1**, CE**1**, IM**1**, SS**1**, DM**1**, SB**1**, and/or CD**1** of FIGS. **4** and **5**; second transmission and reception layers TL**2** and RL**2** may be implemented using TB**2**, CE**2**, IM**2**, SS**2**, DM**2**, SB**2**, and/or CD**2** of FIGS. **4** and **5**: third transmission and reception layers TL**3** and RL**3** may be implemented using TB**3**, CE**3**, IM**3**, SS**3**, DM**3**, SB**3**, and/or CD**3** of FIGS. **4** and **5**; and fourth transmission and reception layers TL**4** and RL**4** may be implemented using TB**4**, CE**4**, IM**4**, SS**4**, DM**4**, SB**4**, and/or CD**4** of FIGS. **4** and **5**. Moreover, first HARQ process HARQ-**1** may map only (without bundling/sharing) to first transmission and reception layers TL**1** and RL**1** for rank **1** and rank **2** transmissions, and first HARQ process HARQ-**1** may map (with bundling/sharing) to both first and second transmission/reception layers TL**1**, RL**1**, TL**2**, and RL**2** for rank **3** and rank **4** downlink transmissions. Second HARQ process HARQ-**2** may map only (without bundling/sharing) to third transmission and reception layers TL**3** and RL**3** for rank **2** and rank **3** downlink transmissions, and second HARQ process HARQ-**2** may map (with bundling/sharing) to both third and fourth transmission/reception layers TL**3**, RL**3**, TL**4**, and RL**4** for rank **4** transmissions. For rank **1** downlink transmissions, second HARQ process HARQ-**2** may be unused.

In each of the tables of FIGS. **10-13**, the "Initial Transmission" heading identifies the status of the most recent HARQ-ACK/NACK message (received from wireless terminal **200**) corresponding to the most recent downlink transmission for the respective HARQ process (i.e., HARQ-**1** and/or HARQ-**2**). More particularly, P (pass) represents a HARQ ACK message received for the respective HARQ process representing successful decoding of all of the data block or blocks associated with the HARQ process. F (fail) represents a HARQ NACK message received for the respective HARQ process representing unsuccessful decoding of any one data block or blocks associate with the HARQ process, and "--" represents non-use of the HARQ process (e.g., HARQ-**2** may be unused for rank **1** downlink transmissions). The "UE reported rank" heading identifies a requested/recommended downlink transmission rank (also referred to as a rank) reported by wireless terminal **200**, and the "Scheduled Rank" heading identified a downlink transmission rank actually scheduled by base station processor **101**. The "Retransmission" HARQ-**1** column identifies whether a new transmission of a new transport data block or blocks (NT) is allowed for the respective HARQ process, whether a retransmission of a previously transmitted data block or blocks (OT) is to be performed for the respective HARQ process, or whether no transmission ("--") is to be performed for the respective HARQ process.

The table of FIG. **10** illustrates base station processor **101** rank schedulings when an initial rank **1** downlink transmission is performed using the first HARQ process HARQ-**1** mapped to first transmission/reception layers TL**1** and RL**1**. Accordingly, the initial transmission includes only a single data block transmitted/received using transmission/reception layers TL**1** and RL**1**, and the resulting ACK/NACK message for the HARQ-**1** process maps to only the single data block (i.e., an ACK message is generated if the single data block passes decoding at CD**1**, or a NACK message is generated if the single data block fails decoding at CD**1**). In each case where the single data block passes P (i.e., rows **1**, **3**, **5**, and **7** of FIG. **10**) decoding (so that an ACK message is received), base station processor **101** may schedule the rank recommended/requested by wireless terminal **200**, and new data NT may be transmitted in accordance with the UE reported rank. With scheduled rank **4**, new first and second data blocks may be transmitted over respective transmission/reception layers TL**1**/RL**1** and TL**2**/RL**2** bundled with HARQ-**1** using a same TFRE, and new third and fourth data blocks may be transmitted over respective transmission/reception layers TL**3**/RL**3** and TL**4**/RL**4** bundled with HARQ-**2** using the same TFRE as shown in row **1** of FIG. **10**. With scheduled rank **3**, new first and second data blocks may be transmitted over respective transmission/reception layers TL**1**/RL**1** and TL**2**/RL**2** bundled with HARQ-**1** using a same TFRE, and a new third data block may be transmitted over respective transmission/reception layers TL**3**/RL**3** using HARQ-**2** without bundling using the same TFRE as shown in row **3** of FIG. **10**. With scheduled rank **2**, a new first data block may be transmitted over transmission/reception layers TL**1**/RL**1** using HARQ-**1** without bundling using a TFRE, and a second data block may be transmitted over transmission/reception layers TL**3**/RL**3** using HARQ-**2** without bundling using the TFRE as shown in row **5** of FIG. **10**. With scheduled rank **1**, a new first data block may be transmitted over transmission/reception layers TL**1**/RL**1** using HARQ-**1** without bundling using the TFRE, and HARQ-**2** may remain unused during the TFRE as shown in row **7** of FIG. **10**.

In cases where the single data block fails F (rows **2**, **4**, **6**, and **8** of FIG. **10**) decoding (so that a NACK message is received), base station processor **101** may consider the reported rank, but base station processor **101** may schedule the downlink transmission rank to maintain a HARQ process mapping to support the retransmission of the failed data block. As shown at rows **2**, **4**, and **6** of FIG. **10**, if wireless terminal **200** reports a higher rank (i.e., a reported rank of **2**, **3**, or **4** with an initial rank of **1**) base station processor **101** may allow scheduling of a rank **2** transmission to maintain a mapping of HARQ-**1** only (without bundling/sharing) to transmission/reception layers TL**1** and RL**1** for the retransmission of the initially failed data block (OT) using a TFRE while allowing transmission of a new data block (NT) using a mapping of HARQ-**2** only (without bundling/sharing) to transmission/reception layers TL**3** and RL**3** using the TFRE. In an alternative to scheduling rank **2** at rows **2**, **4**, and **6** of FIG. **10**, base station processor **101** may schedule rank **1** to retransmit the failed data block maintaining a mapping of HARQ-**1** only to transmission/reception layers TL**1** and RL**1** without transmitting a new data block using HARQ-**2**. If the reported rank is the same as the initial rank as shown in row **8** of FIG. **10**, the scheduled rank may remain unchanged so that the mapping of HARQ-**1** to transmission/reception layers TL**1**/RL**1** is unchanged and so that the failed data block may be retransmitted using the same HARQ-**1** mapping.

The table of FIG. **11** illustrates base station processor **101** rank schedulings when an initial rank **2** downlink transmission is performed using the first HARQ process HARQ-**1** mapped to first transmission/reception layers TL**1** and RL**1** (without bundling/sharing) and using the second HARQ pro-

cess HARQ-2 mapped to third transmission/reception layers TL3 and RL3 (without bundling/sharing). Accordingly, the initial transmission includes a first data block transmitted/received using transmission/reception layers TL1 and RL1 and a second data block transmitted/received using transmission/reception layers TL3 and RL3. The resulting ACK/NACK message for the HARQ-1 process maps to only the first data block (i.e., an ACK message is generated if the first data block passes decoding at CD1, or a NACK message is generated if the single data block fails decoding at CD1), and the resulting ACK/NACK message for the HARQ-2 process maps to only the second data block (i.e., an ACK message is generated if the second data block passes decoding at CD3, or a NACK message is generated if the second data block fails decoding at CD3).

In each case where both of the first and second data blocks pass P (i.e., rows 1, 5, 9, and 13) decoding (so that two ACK messages are received), base station processor 101 may schedule the rank recommended/requested by wireless terminal 200, and new data NT may be transmitted in accordance with the UE reported rank. With scheduled rank 4, new first and second data blocks may be transmitted over respective transmission/reception layers TL1/RL1 and TL2/RL2 bundled with HARQ-1 using a same TFRE, and new third and fourth data blocks may be transmitted over respective transmission/reception layers TL3/RL3 and TL4/RL4 bundled with HARQ-2 using the same TFRE as shown in row 1 of FIG. 11. With scheduled rank 3, new first and second data blocks may be transmitted over respective transmission/reception layers TL1/RL1 and TL2/RL2 bundled with HARQ-1 using a same TFRE, and a new third data block may be transmitted over respective transmission/reception layers TL3/RL3 using HARQ-2 without bundling using the same TFRE as shown in row 5 of FIG. 11. With scheduled rank 2, a new first data block may be transmitted over transmission/reception layers TL1/RL1 using HARQ-1 without bundling using a TFRE, and a second data block may be transmitted over transmission/reception layers TL3/RL3 using HARQ-2 without bundling using the TFRE as shown in row 9 of FIG. 11. With scheduled rank 1, a new first data block may be transmitted over transmission/reception layers TL1/RL1 using HARQ-1 without bundling using the TFRE, and HARQ-2 may remain unused during the TFRE as shown in row 13 of FIG. 11.

In each case where wireless terminal 200 reports a recommended/requested rank 2 that is the same as the initial rank (as in rows 9, 10, 11, and 12 of FIG. 11), base station processor 101 may maintain the same scheduled rank (i.e., rank 2) regardless of the pass/fail status of the initially transmitted data blocks. The same rank 2 HARQ process mappings for HARQ-1 and HARQ-2 are maintained for the next transmission/retransmission regardless of the status P/F of the initial rank 2 transmission. Accordingly, retransmissions of one or both of the first and second data blocks (OT) may be supported using the same HARQ mappings, and/or new data blocks may be transmitted for either or both HARQ processes for which initial decoding passed.

When wireless terminal 200 reports a higher rank (i.e. rank 3 or rank 4) and the first data block (mapped to HARQ-1 without bundling/sharing) of the initial transmission fails F decoding resulting in a HARQ-1 NACK message (as in rows 3, 4, 7, and 8 of FIG. 11), base station processor 101 may select rank 2 to maintain the same downlink transmission rank. The same rank 2 HARQ process mappings for HARQ-1 and HARQ-2 are thus maintained for the retransmission of the first data block that failed and for the possible retransmission of the second data block using HARQ-2 if it failed or the transmission of a new data block using HARQ-2 if the initial second data block passed. According to one alternative of row 7 of FIG. 11, base station processor 101 may schedule a lower rank 1 transmission if the second data block of HARQ-2 passed to support retransmission of the first data block of HARQ-1 without transmitting a new data block using HARQ-2.

When wireless terminal 200 reports a higher rank (i.e., rank 3 or rank 4) when the first data block (mapped to HARQ-1 without bundling/sharing) of the initial transmission passes P decoding, and when the second data block (mapped to HARQ-2 without bundling/sharing) of the initial transmission fails F decoding resulting in a HARQ-2 NACK message (as in rows 2 and 6 of FIG. 11), base station processor 101 may select rank 3 (at rows 2 and 6 of FIG. 11) to maintain the same HARQ-2 mapping to transmission/reception layers TL3/RL3 (without sharing/bundling) while allowing HARQ-1 to be mapped to transmission/reception layers TL1/RL1 and TL2/RL2 to allow transmission of two new data blocks NT using the HARQ-1 process. Stated in other words, a higher rank may be allowed even though the second data block failed because the mapping of HARQ-2 to transmission/reception layers TL3/RL3 (without sharing/bundling) is the same for both rank 2 and rank 3 transmissions. While the mapping of HARQ-1 is different for rank 2 and rank 3 transmissions, a same mapping of HARQ-1 is not required because the initial HARQ-1 data block passed. Accordingly, a higher data rate rank 3 transmission (allowing retransmission of the one HARQ-2 data packed that failed and 2 new HARQ-1 data packets) may be allowed while supporting the HARQ-2 retransmission.

At row 14 of FIG. 11, if the first data block (of HARQ-1) of the initial transmission passes (P), if the second data block (HARQ-2) of the initial transmission fails (F), and wireless terminal 200 reports rank 1, base station processor may schedule an alternative rank one transmission retransmitting the second data block of the initial transmission using HARQ-2 (without bundling/sharing) over transmission/reception layers TL3/RL3. In an alternative at row 14 of FIG. 11, rank 2 may be scheduled to support transmission of a new data block over transmission/reception layers TL1/RL1 using HARQ-1 and retransmission of the second data block over transmission/reception layers TL3/RL3 using HARQ-2.

At row 15 of FIG. 11, if the first data block (of HARQ-1) of the initial transmission fails (F), if the second data block (HARQ-2) of the initial transmission passes (P), and wireless terminal 200 reports rank 1, base station processor 101 may schedule a conventional rank one transmission retransmitting the first data block of the initial transmission using HARQ-1 (without bundling/sharing) over transmission/reception layers TL1/RL1. At row 16 of FIG. 11, if both of the first data block (HARQ-1) and the second data block (HARQ-2) of the initial transmission fail (F) and wireless terminal 200 reports rank 1, base station processor 101 may force a rank 2 transmission to maintain the mappings of HARQ-1 to transmission/reception layers TL1/RL1 and HARQ-2 to transmission/reception layers TL3/RL3 for retransmissions of both of the failed data blocks.

The table of FIG. 12 illustrates base station processor 101 rank schedulings when an initial rank 3 downlink transmission is performed using the first HARQ process HARQ-1 mapped to first and second transmission/reception layers TL1/RL1 and TL2/RL2 (with bundling/sharing) and using the second HARQ process HARQ-2 mapped to third transmission/reception layers TL3/RL3 (without bundling/sharing). Accordingly, the initial transmission includes a first data block transmitted/received using transmission/reception lay-

ers TL1/RL1, and second data block transmitted/received using transmission/reception layers TL2/RL2, and a third data block transmitted/received using transmission/reception layers TL3/RL3. The resulting ACK/NACK message for the HARQ-1 process thus maps to the first and second data blocks (i.e., an ACK message is generated if both the first and second data blocks pass decoding at CD1 and CD2, or a NACK message is generated if either or both of the first and second data block fail decoding at CD1/CD2), and the resulting ACK/NACK message for the HARQ-2 process maps to only the third data block (i.e., an ACK message is generated if the third data block passes decoding at CD3, or a NACK message is generated if the third data block fails decoding at CD3).

If each of the first, second, and third data blocks pass decoding so that both HARQ-1 and HARQ-2 pass P (i.e., so two ACK messages are received), base station processor **101** may schedule the rank recommended/requested by wireless terminal **200** (as in rows **1**, **5**, **9**, and **13** of FIG. **12**), and new data NT may be transmitted in accordance with the UE reported rank. With scheduled rank **4**, new first and second data blocks may be transmitted over respective transmission/reception layers TL1/RL1 and TL2/RL2 bundled with HARQ-1 using a same TFRE, and new third and fourth data blocks may be transmitted over respective transmission/reception layers TL3/RL3 and TL4/RL4 bundled with HARQ-2 using the same TFRE as shown in row **5** of FIG. **12**. With scheduled rank **3**, new first and second data blocks may be transmitted over respective transmission/reception layers TL1/RL1 and TL2/RL2 bundled with HARQ-1 using a same TFRE, and a new third data block may be transmitted over respective transmission/reception layers TL3/RL3 using HARQ-2 without bundling using the same TFRE as shown in row **1** of FIG. **12**. With scheduled rank **2**, a new first data block may be transmitted over transmission/reception layers TL1/RL1 using HARQ-1 without bundling using a TFRE, and a second data block may be transmitted over transmission/reception layers TL3/RL3 using HARQ-2 without bundling using the TFRE as shown in row **9** of FIG. **12**. With scheduled rank **1**, a new first data block may be transmitted over transmission/reception layers TL1/RL1 using HARQ-1 without bundling using the TFRE, and HARQ-2 may remain unused during the TFRE as shown in row **13** of FIG. **12**.

In each case where wireless terminal **200** reports a recommended/requested rank **3** that is the same as the initial rank (as in rows **1**, **2**, **3**, and **4** of FIG. **13**), base station processor **101** may maintain the same scheduled rank (i.e. rank **3**). The same rank **2** HARQ process mappings for HARQ-1 and HARQ-2 are maintained for the next transmission/retransmission regardless of the status P/F of the initial rank **3** transmission. Accordingly, retransmissions of the first and second data blocks (OT) of HARQ-1 and/or retransmission of the third data block (OT) of HARQ-2 may be supported using the same HARQ mappings, and/or new data blocks may be transmitted for either or both HARQ processes for which initial decoding passed.

When wireless terminal **200** reports a higher rank (i.e., rank **4**) and the third data block (mapped to HARQ-2 without bundling/sharing) of the initial transmission fails F decoding resulting in a HARQ-2 NACK message (as in rows **6** and **8** of FIG. **12**), base station processor **101** may maintain rank **3** to maintain the same rank **3** HARQ process mappings for HARQ-1 and HARQ-2. Accordingly, any needed retransmissions may be supported.

When wireless terminal **200** reports a higher rank (i.e. rank **4**) and the third data block (mapped to HARQ-2 without bundling/sharing) of the initial transmission passes decoding resulting in a HARQ-2 ACK message (as in rows **5** and **7** of FIG. **12**), base station processor **101** may schedule rank **4** so that HARQ-1 is mapped to transmission/reception layers TL1/RL1 and TL2/RL2 and so that HARQ-2 is mapped to transmission/reception layers TL3/RL3 and TL4/RL4. Here the HARQ-1 mapping is unchanged between rank **3** and rank **4** to support retransmission of first and second data blocks mapped to HARQ-1 if needed as shown at row **7** of FIG. **12**.

When wireless terminal **200** reports rank **2** and the first and second data blocks (mapped to HARQ-1 with sharing/bundling) pass decoding resulting in a HARQ-1 ACK message (as in rows **9** and **10** of FIG. **12**), base station processor **101** may schedule rank **2** so that HARQ-1 is mapped to transmission/reception layers TL1/RL1 (without sharing/bundling) and so that HARQ-2 is mapped to transmission/reception layers TL3/RL3 (without sharing/bundling). Accordingly, a mapping of HARQ-2 to transmission/reception layers TL3/RL3 is the same for rank **2** and rank **3** downlink transmissions. Because both of the first and second data blocks of the initial HARQ-1 transmission passed decoding, retransmission using the HARQ-1 process is not required and remapping of the HARQ-1 process can occur without affecting any HARQ-1 retransmissions.

When wireless terminal **200** reports rank **2** and either or both of the first and second data blocks (mapped to HARQ-1 with sharing/bundling) fail decoding (F) resulting in a HARQ-1 NACK message (as in rows **11** and **12** of FIG. **12**), base station processor **101** may continue scheduling rank **3** (as in rows **11** and **12** of FIG. **12**) so that mappings of HARQ-1 and HARQ-2 remain unchanged (i.e., HARQ-1 maps to transmission/reception layers TL1/RL1 and TL2/RL2 and HARQ-2 maps to transmission/reception layer TL3/RL3). Accordingly, retransmissions of first and second data blocks of HARQ-1 may be supported, and retransmission of third data block of HARQ-2 may be supported if needed (at row **12** of FIG. **12**).

At row **14** of FIG. **12**, if the first and second data blocks (mapped to HARQ-1) of the initial transmission pass (P), if the third data block (mapped to HARQ-2) of the initial transmission fails (F), and wireless terminal **200** reports rank **1**, base station processor **101** may schedule an alternative rank one transmission retransmitting the third data block of the initial transmission using HARQ-2 (without bundling/sharing) over transmission/reception layers TL3/RL3. In another alternative at row **14**, base station processor may schedule a conventional rank **2** transmission so that a new data block may be transmitted using transmission/reception layers TL1/RL1 and HARQ-1 and so that the third data block may be may be retransmitted.

At rows **15** and **16** of FIG. **12**, if either or both of the first data blocks (mapped to HARQ-1) of the initial transmission fails (F), and wireless terminal **200** reports rank **1**, base station processor **101** may continue scheduling rank **3** to support retransmission of the first and second data blocks that are mapped to HARQ-1.

The table of FIG. **13** illustrates base station processor **101** rank schedulings when an initial rank **4** downlink transmission is performed using the first HARQ process HARQ-1 mapped to first and second transmission/reception layers TL1/RL1 and TL2/RL2 (with bundling/sharing) and using the second HARQ process HARQ-2 mapped to third and fourth transmission/reception layers TL3/RL3 and TL4/RL4 (with bundling/sharing). Accordingly, the initial transmission includes a first data block transmitted/received using transmission/reception layers TL1/RL1, and second data block transmitted/received using transmission/reception layers TL2/RL2, a third data block transmitted/received using transmission/reception layers TL3/RL3, and a fourth data block

transmitted using transmission/reception layers TL4/RL4. The resulting ACK/NACK message for the HARQ-1 process thus maps to the first and second data blocks (i.e., an ACK message is generated if both the first and second data blocks pass decoding at CD1 and CD2, or a NACK message is generated if either or both of the first and second data block fail decoding at CD1/CD2), and the resulting ACK/NACK message for the HARQ-2 process maps to the third and fourth data blocks (i.e., an ACK message is generated if both the third and fourth data blocks pass decoding at CD3 and CD4, or a NACK message is generated if either or both of the third and fourth data blocks fail decoding at CD3/CD4).

In each case where all of the first, second, third and fourth data blocks pass decoding so that both HARQ-1 and HARQ-2 pass P (i.e., so two ACK messages are received), base station processor **101** may schedule the rank recommended/requested by wireless terminal **200** (as in rows **1**, **5**, **9**, and **13** of FIG. **13**), and new data NT may be transmitted in accordance with the UE reported rank. With scheduled rank **4**, new first and second data blocks may be transmitted over respective transmission/reception layers TL1/RL1 and TL2/RL2 bundled with HARQ-1 using a same TFRE, and new third and fourth data blocks may be transmitted over respective transmission/reception layers TL3/RL3 and TL4/RL4 bundled with HARQ-2 using the same TFRE as shown in row **1** of FIG. **13**. With scheduled rank **3**, new first and second data blocks may be transmitted over respective transmission/reception layers TL1/RL1 and TL2/RL2 bundled with HARQ-1 using a same TFRE, and a new third data block may be transmitted over respective transmission/reception layers TL3/RL3 using HARQ-2 without bundling using the same TFRE as shown in row **5** of FIG. **13**. With scheduled rank **2**, a new first data block may be transmitted over transmission/reception layers TL1/RL1 using HARQ-1 without bundling using a TFRE, and a second data block may be transmitted over transmission/reception layers TL3/RL3 using HARQ-2 without bundling using the TFRE as shown in row **9** of FIG. **13**. With scheduled rank **1**, a new first data block may be transmitted over transmission/reception layers TL1/RL1 using HARQ-1 without bundling using the TFRE, and HARQ-2 may remain unused during the TFRE as shown in row **13** of FIG. **13**.

In each case where wireless terminal **200** reports a recommended/requested rank **4** that is the same as the initial rank (as in rows **1**, **2**, **3**, and **4** of FIG. **13**), base station processor **101** may maintain the same scheduled rank (i.e., rank **4**). The same rank **4** HARQ process mappings for HARQ-1 and HARQ-2 are maintained for the next transmission/retransmission regardless of the status P/F of the initial rank **4** transmission. Accordingly, retransmissions of the first and second data blocks (OT) of HARQ-1 and/or retransmission of the third and fourth data blocks (OT) of HARQ-2 may be supported using the same HARQ mappings, and/or new data blocks may be transmitted for either or both HARQ processes for which initial decoding passed.

When wireless terminal **200** reports a lower rank (e.g., rank **3**, rank **2**, or rank **1**) and either or both of the third or fourth data blocks (mapped to HARQ-2 with sharing/bundling) fail decoding F resulting in a HARQ-2 NACK message (as in rows **6**, **8**, **10**, **12**, **14**, or **16** of FIG. **13**), base station processor **101** may continue scheduling rank **4** so that HARQ-2 is mapped to the third and fourth transmission/reception layers TL3/RL3 and TL4/RL4 to support retransmission of the third and fourth data blocks. By continuing rank **4**, HARQ-1 may continue to be mapped to transmission/reception layers TL1/RL1 and TL2/RL2 to support retransmission of the first and second data blocks (mapped to HARQ-1 with sharing/bundling) if needed (e.g., at rows **8**, **12**, or **16** of FIG. **13**), or two new data blocks may be transmitted using HARQ-1 (e.g., at rows **6**, **10**, or **14** of FIG. **13**).

When wireless terminal **200** reports rank **3** and the third and fourth data blocks (mapped to HARQ-2 with sharing/bundling) pass decoding P resulting in a HARQ-2 ACK message (as in rows **5** and **7** of FIG. **13**), base station processor **101** may scheduling rank **3** so that HARQ-1 is mapped to the first and second transmission/reception layers TL1/RL1 and TL2/RL2 (with bundling/sharing) to support retransmission of the first and second data blocks if needed, and so that HARQ-2 is mapped to the third transmission/reception layer TL3/RL3 (without bundling/sharing).

When wireless terminal **200** reports rank **2** and either or both of the first and second data blocks (mapped to HARQ-1 with sharing/bundling) fail decoding resulting in a HARQ-1 NACK message and both of the third and fourth data blocks (mapped to HARQ-2) pass decoding resulting in a HARQ-2 ACK (as in row **11** of FIG. **13**), base station processor **101** may schedule rank **3** so that HARQ-1 is mapped to transmission/reception layers TL1/RL1 and TL2/RL2 (with sharing/bundling) and so that HARQ-2 is mapped to transmission/reception layers TL3/RL3 (without sharing/bundling). Accordingly, a mapping of HARQ-1 to transmission/reception layers TL1/RL1 and TL2/RL2 is the same for rank **3** and rank **4** downlink transmissions to support retransmission of the first and second data blocks. Because both of the third and fourth data blocks of the initial HARQ-2 transmission passed decoding, retransmission using the HARQ-2 process is not required and remapping of the HARQ-2 process can occur without affecting any HARQ-2 retransmissions.

When wireless terminal **200** reports rank **1** and either or both of the first and second data blocks (mapped to HARQ-1 with sharing/bundling) fail decoding (F) resulting in a HARQ-1 NACK message and both of the third and fourth data blocks (mapped to HARQ-2 with sharing/bundling) pass decoding (P) resulting in a HARQ-2 ACK messages at in row **15** of FIG. **13**, base station processor **101** may schedule rank **3** so that mappings of HARQ-1 remain unchanged (i.e., HARQ-1 maps to transmission/reception layers TL1/RL1 and TL2/RL2). Accordingly, retransmissions of first and second data blocks of HARQ-1 may be supported, and HARQ-2 may be mapped to transmission/reception layers TL1/RL1 (without bundling/sharing) for transmission of a new data block.

As set forth in the tables of FIGS. **10-13**, P may represent an ACK for the respective HARQ process, and F may represent a NACK for the respective HARQ process. Moreover, NT (new transmission) represents a new transmission of a new data block(s), and OT (old transmission) represents a retransmission of a previously transmitted data block(s) for which the associate HARQ process generated a NACK.

According to embodiments discussed above, radio base station processor **101** may select a MIMO transmission rank for a subsequent downlink transmission responsive to a rank reported (e.g., requested/recommended) by wireless terminal **200**, but base station processor **101** may deviate from the reported rank if a NACK has been received for one or more HARQ processes used for a preceding downlink transmission. More particularly, wireless terminal **200** may deviate from the reported rank to select a MIMO transmission rank that maintains a HARQ process mapping from the preceding downlink transmission if the HARQ process generated a NACK for the preceding downlink transmission. When two HARQ processes are used in a 4 antenna system supporting up to 4 downlink data streams (i.e., up to rank **4**), for example, if an initial downlink transmission has rank **2** or higher and

both HARQ processes generate NACKs, base station processor **101** may maintain the same rank for the next transmission (even if a lower or a higher rank was reported) to support retransmission of all data blocks of both HARQ processes (see, rows **4**, **8**, **12**, and **16** of FIG. **11**; rows **4**, **8**, **12**, and **16** of FIG. **12**; and rows **4**, **8**, **12**, and **16** of FIG. **13**). If all HARQ processes used in an initial downlink transmission generate ACKs, base station processor **101** may change the rank for the next transmission to any rank reported by wireless terminal **200** (see, rows **1**, **3**, **5**, **7** of FIG. **10**; rows **1**, **5**, **9**, and **13** of FIG. **11**; rows **1**, **5**, **9**, and **13** of FIG. **12**; and rows **1**, **5**, **9**, and **13** of FIG. **13**). If a bundled/shared HARQ process used in an initial downlink transmission generates a NACK, base station processor **101** may require a rank of three or higher for the next transmission.

According to some embodiments of present inventive concepts, a first transmission/reception layer (corresponding to a stream of data codewords CW**1**) may be supported using TB**1**, CE**1**, IM**1**, and/or SS**1** at base station **100** and using DM**1**, SB**1**, and/or CD**1** at wireless terminal **200**; a second transmission/reception layer (corresponding to a stream of data codewords CW**2**) may be supported using TB**2**, CE**2**, IM**2**, and/or SS**2** at base station **100** and using DM**2**, SB**2**, and/or CD**2** at wireless terminal **200**; a third transmission/reception layer (corresponding to a stream of data codewords CW**3**) may be supported using TB**3**, CE**3**, IM**3**, and/or SS**3** at base station **100** and using DM**3**, SB**3**, and/or CD**3** at wireless terminal **200**; and a fourth transmission/reception layer (corresponding to a stream of data codewords CW**4**) may be supported using TB**4**, CE**4**, IM**4**, and/or SS**4** at base station **100** and using DM**4**, SB**4**, and/or CD**4** at wireless terminal **200**. As shown in FIG. **14** for rank **1** transmission/reception, a single stream of data codewords CW**1** may be transmitted/received using the first transmission/reception layer (e.g., including TB**1**, CE**1**, IM**1**, and/or SS**1** at base station **100** and including DM**1**, SB**1**, and/or CD**1** at wireless terminal **200**) without using the second, third, and fourth transmission/reception layers, and a first HARQ process/codeword (HARQ-**1**) may be mapped directly to the single stream of data codewords CW**1**. As shown in FIG. **14** for rank **2** transmission/reception, a first stream of data codewords CW**1** may be transmitted/received using the first transmission/reception layer (e.g., including TB**1**, CE**1**, IM**1**, and/or SS**1** at base station **100** and including DM**1**, SB**1**, and/or CD**1** at wireless terminal **200**), and a second stream of data codewords CW**2** may be transmitted/received using the second transmission/reception layer (e.g., including TB**2**, CE**2**, IM**2**, and/or SS**2** at base station **100** and including DM**2**, SB**2**, and/or CD**2** at wireless terminal **200**), without using the third and fourth transmission/reception layers. For rank **2** transmission/reception, the first HARQ process/codeword (HARQ-**1**) may be mapped directly to the first stream of data codewords CW**1**, and a second HARQ process/codeword (HARQ-**2**) may be mapped directly to the second stream of data codewords CW**2**. For rank **1** and **2** transmission/reception of FIG. **14**, each stream of codewords may be mapped directly to a respective HARQ process/codeword without bundling as discussed above.

As shown in FIG. **14** for rank **3** transmission/reception, a first stream of data codewords CW**1** may be transmitted/received using the first transmission/reception layer (e.g., including TB**1**, CE**1**, IM**1**, and/or SS**1** at base station **100** and including DM**1**, SB**1**, and/or CD**1** at wireless terminal **200**), a second stream of data codewords CW**2** may be transmitted/received using the second transmission/reception layer (e.g., including TB**2**, CE**2**, IM**2**, and/or SS**2** at base station **100** and including DM**2**, SB**2**, and/or CD**2** at wireless terminal **200**), and a third stream of data codewords CW**3** may be transmitted/received using the third transmission/reception layer (e.g., including TB**3**, CE**3**, IM**3**, and/or SS**3** at base station **100** and including DM**3**, SB**3**, and/or CD**3** at wireless terminal **200**), without using the fourth transmission/reception layer. For rank three transmission/reception, the first HARQ process/codeword (HARQ-**1**) may be mapped directly to the first stream of data codewords CW**1**, while the second HARQ process/codeword (HARQ-**2**) may be mapped to both of the second and third streams of data codewords CW**2** and CW**3**. For rank **3** transmission/reception, the first stream of codewords may be mapped directly to the first HARQ process/codeword without bundling, while the second and third streams of codewords may be bundled with the second HARQ process.

As shown in FIG. **14** for rank **4** transmission/reception, a first stream of data codewords CW**1** may be transmitted/received using the first transmission/reception layer (e.g., including TB**1**, CE**1**, IM**1**, and/or SS**1** at base station **100** and including DM**1**, SB**1**, and/or CD**1** at wireless terminal **200**), a second stream of data codewords CW**2** may be transmitted/received using the second transmission/reception layer (e.g., including TB**2**, CE**2**, IM**2**, and/or SS**2** at base station **100** and including DM**2**, SB**2**, and/or CD**2** at wireless terminal **200**), a third stream of data codewords CW**3** may be transmitted/received using the third transmission/reception layer (e.g., including TB**3**, CE**3**, IM**3**, and/or SS**3** at base station **100** and including DM**3**, SB**3**, and/or CD**3** at wireless terminal **200**), and a fourth stream of data codewords CW**4** may be transmitted/received using the fourth transmission/reception layer (e.g., including TB**4**, CE**4**, IM**4**, and/or SS**4** at base station **100** and including DM**4**, SB**4**, and/or CD**4** at wireless terminal **200**). Moreover, the first HARQ process/codeword (HARQ-**1**) may be mapped to both of the first and fourth streams of data codewords CW**1** and CW**4**, and the second HARQ process/codeword (HARQ-**2**) may be mapped to both of the second and third streams of data codewords CW**2** and CW**3**. For rank **4** transmission/reception, the first and second streams of codewords may be bundled with first HARQ process/codeword, while the second and third streams of codewords may be bundled with the second HARQ process.

According to embodiments of FIG. **14** the first transmission/reception layer TL**1**/RL**1** (transmitted using TB**1**, CE**1**, IM**1**, and/or SS**1** at base station **100** and received using DM**1**, SB**1**, and/or CD**1** at wireless terminal **200**) may support transmission/reception of data codewords CW**1**, and the first transmission layer may be mapped to the first HARQ process (HARQ-**1**) for transmission according to ranks **1**, **2**, **3**, and **4**. The second transmission/reception layer TL**1**/RL**1** (transmitted using TB**2**, CE**2**, IM**2**, and/or SS**2** at base station **100** and received using DM**2**, SB**2**, and/or CD**2** at wireless terminal **200**) may support transmission/reception of data codewords CW**2**, and the second transmission layer may be mapped to the second HARQ process (HARQ-**2**) for transmission according to ranks **2**, **3**, and **4**. The third transmission/reception layer TL**3**/RL**3** (transmitted using TB**2**, CE**3**, IM**3**, and/or SS**3** at base station **100** and received using DM**3**, SB**3**, and/or CD**3** at wireless terminal **200**) may support transmission/reception of data codewords CW**3**, and the third transmission layer may be mapped to the second HARQ process (HARQ-**2**) for transmission according to ranks **3** and **4**. The fourth transmission/reception layer TL**4**/RL**4** (transmitted using TB**4**, CE**4**, IM**4**, and/or SS**4** at base station **100** and received using DM**4**, SB**4**, and/or CD**4** at wireless terminal **200**) may support transmission/reception of data codewords CW**4**, and the fourth transmission layer may be mapped to the second HARQ process (HARQ-**2**) for transmission according

to rank **4**. Accordingly, each transmission/reception layer (when used) is mapped to a same HARQ process regardless of the transmission/reception rank being use. Accordingly, each wireless terminal decoder and soft buffer may be mapped to a same HARQ processes for any rank using the decoder and soft buffer.

According to embodiments of FIG. **14**: a mapping of layer **1** to the first HARQ process HARQ-**1** remains the same for ranks **1**, **2**, **3**, and **4**: a mapping of layer **2** to the second HARQ process HARQ-**2** remains the same for ranks **2**, **3**, and **4**; and a mapping of layer **3** to the second HARQ process HARQ-**2** remains the same for ranks **3** and **4**. Accordingly, if the rank changes between ranks **3** and **4**, the bundled mapping of layers **2** and **3** to the second HARQ process HARQ-**2** stays the same, thereby supporting retransmissions over layers **2** and **3** while changing to either rank **3** or rank **4** with HARQ **2** bundled to the 2^{nd} and 3^{rd} layers. Similarly, if the rank changes between ranks **1** and **2**, between ranks **2** and **3**, or between ranks **1** and **3**, the direct mapping of layer **1** to the first HARQ process HARQ-**1** stays the same, thereby supporting retransmissions over layer **1** while changing to rank **1**, rank **2**, or rank **3** with HARQ-**1** bundled to the first layer (without bundling). Partial retransmission (e.g. where previously transmitted data for one HARQ process is retransmitted and new data for the other HARQ process is initially transmitted during the same TTI) may thus be supported while changing rank as long as the layer or layers mapped to the HARQ process for the retransmission is unchanged.

Wireless terminal processor **201** and/or transceiver **209** may define a plurality of reception layers/streams as discussed above with respect to FIGS. **4** and/or **5**: with a first layer RL**1** being used for MIMO ranks **1**, **2**, **3**, and **4**: with a second layer RL**2** being used for MIMO ranks **2**, **3**, and **4**; with a third layer RL**3** being used for MIMO ranks **3** and **4**; and with a fourth MIMO layer RL**4** being used for MIMO rank **4**. Separate decoding (e.g., using decoder functionally illustrated by decoders CD**1**-**4** of FIG. **5**) may be performed for each MIMO layer received during a MIMO TTI. Wireless terminal processor **201**, for example, may define, configure, and/or use one or more of reception layers RL**1**, RL**2**, RL**3**, and/or RL**4** for a given TTI/TFRE responsive to rank and/or precoding vector information provided from base station **100** via downlink signaling as discussed above with respect to FIG. **3**A. For example, a higher MIMO rank (defining a respective higher number of reception layers/streams) may be selected when the wireless terminal detects that the downlink channel has a higher SINR (e.g., when the wireless terminal is relatively close to the base station), and a lower MIMO rank (defining a respective lower number of reception layers/streams) may be selected when the wireless terminal detects that the downlink channel has a lower SINR (e.g., when the wireless terminal is relatively distant from the base station).

While separate transport block generator, encoder, modulator, layer mapper, spreader/scrambler, and layer precoder blocks are illustrated in FIG. **4** by way of example, the blocks of FIG. **4** merely illustrate functionalities/operations of base station processor **101** and/or transceiver **109**. Sub-blocks (e.g., transport blocks TB**1**-TB**4** channel encoders CE**1**-CE**4**, interleavers/modulators IM**1**-IM**4**, and spreader scramblers SS**1**-SS**4**) of FIG. **4** further illustrate functionalities/operations of transport block generator, encoder block, modulator block, and spreader/scrambler block supporting transmission layers TL**1**-TL**4**. Processor **101**, however, may provide/define/configure functionality/operations of only one transmission layer TL**1** during rank **1** transmission; processor **101** may provide/define/configure functionality/operations of only two transmission layers TL**1** and TL**2** during rank **2** transmission; processor **101** may provide/define/configure functionality/operations of only **3** transmission layers TL**1**, TL**2**, and TL**3** during rank **3** transmission; and functionality/operations of four transmission layers TL**1**, TL**2**, TL**3**, and TL**4** may only be provided during rank **4** transmission. When multiple transmission layers are provided/defined/configured, for example, processor **101** may provide/define/configure functionality/operations of multiple transport block sub-blocks, multiple channel decoder sub-blocks, multiple interleaver/modulator sub-blocks, and/or multiple spreader/scrambler sub-blocks to allow parallel processing of data of different transmission layers before transmission during a TTI/TFRE, or processor **101** may provide/define/configure functionality/operations of a single transport block, a single channel encoder, a single interleaver/modulator, and/or a single spreader scrambler to allow serial processing of data of different transmission layers before transmission during a TTI/TFRE.

While separate layer decoder, layer demapper, demodulator/deinterleaver, soft buffer, channel decoder, and transport block combiner blocks/sub-blocks are illustrated in FIG. **5** by way of example, the blocks of FIG. **5** merely illustrate functionalities/operations of wireless terminal processor **201** and/or transceiver **209**. For example, sub-blocks (e.g., demodulator/deinterleaver DM**1**-DM**4**, soft buffers SB**1**-SB**4**, and channel decoders CD**1**-CD**4**) of FIG. **5** illustrate functionalities/operations providing reception layers RL**1**-RL**4**. Processor **101** however, may provide/define/configure functionality/operations of only one reception layer RL**1** during rank **1** reception; processor **101** may provide/define/configure functionality/operations of only two reception layers RL**1** and RL**2** during rank **2** transmission; processor **101** may provide/define/configure functionality/operations of only **3** reception layers RL**1**, RL**2**, and RL**3** during rank **3** transmission; and functionality/operations of four reception layers RL**1**, RL**2**, RL**3**, and RL**4** may only be provided during rank **4** transmission. When multiple reception layers are provided/defined/configured, for example, processor **101** may provide/define/configure functionality/operations of multiple demodulator/deinterleaver blocks, multiple soft buffer blocks, and/or multiple channel decoder blocks to allow parallel processing of data of different reception layers during a TTI/TFRE or processor **101** may provide/define/configure functionality/operations of a single demodulator/deinterleaver block, a single soft buffer, and/or a single channel decoder to allow serial processing of data of different reception layers during a TTI/TFRE.

According to embodiments of present inventive concepts discussed above with respect to FIG. **14**, base station processor **101** may use mapping tables of FIGS. **15**-**18** to retransmit failed data packets (e.g., associated with a bundled HARQ process) as an alternative to using mapping tables of FIGS. **10**-**13** as discussed above with respect to operations of FIG. **9** when wireless terminal **200** reports/requests a downlink transmission rank that is different than the downlink transmission rank used to initially transmit the now failed data packets. These embodiments will now be discussed in greater detail below with respect to the tables of FIGS. **15**-**18** for systems including 4 transmit and 4 receive MIMO antennas supporting one, two, three, and four MIMO transmission ranks. While embodiments relating to 4 transmit and 4 receive MIMO antennas are discussed by way of example, embodiments of present inventive concepts may be applied to systems including fewer and/or more MIMO transmit and receive antennas.

If retransmission of previously transmitted data blocks using a shared/bundled HARQ process(es) is required at block **903** of FIG. **9**, base station processor **101** may select a

DL transmission rank at block **905** to maintain a same HARQ process mapping for any such retransmissions as set forth in the tables of FIGS. **15-18**. The headings, acronyms, and abbreviations of FIGS. **15-18** have the same meanings as those discussed above with respect to FIGS. **10-13**.

The table of FIG. **15** illustrates base station processor **101** rank schedulings when an initial rank **1** downlink transmission is performed using the first HARQ process HARQ-**1** mapped to first transmission/reception layers TL**1**/RL**1**. Accordingly, the initial transmission includes only a single data block transmitted/received using transmission/reception layers TL**1**/RL**1**, and the resulting ACK/NACK message for the HARQ-**1** process maps to only the single data block (i.e., an ACK message is generated if the single data block passes decoding at CD**1**, or a NACK message is generated if the single data block fails decoding at CD**1**). In each case where the single data block passes P (i.e., rows **1**, **3**, **5**, and **7** of FIG. **15**) decoding (so that an ACK message is received), base station processor **101** may schedule the rank reported/requested by wireless terminal **200**, and new data NT may be transmitted in accordance with the UE reported rank. With scheduled rank **4**, new first and fourth data blocks may be transmitted over respective transmission/reception layers TL**1**/RL**1** and TL**4**/RL**4** bundled with HARQ-**1** using a same TFRE, and new second and third data blocks may be transmitted over respective transmission/reception layers TL**2**/RL**2** and TL**3**/RL**3** bundled with HARQ-**2** using the same TFRE as shown in row **1** of FIG. **15**. With scheduled rank **3**, a new first data block may be transmitted over respective transmission/reception layers TL**1**/RL**1** using HARQ-**1** using a TFRE without bundling, and new second and third data blocks may be transmitted over respective transmission/reception layers TL**2**/TL**2** and TL**3**/RL**3** bundled with HARQ-**2** using the same TFRE as shown in row **3** of FIG. **15**. With scheduled rank **2**, a new first data block may be transmitted over transmission/reception layers TL**1**/RL**1** using HARQ-**1** without bundling using a TFRE, and a second data block may be transmitted over transmission/reception layers TL**2**/RL**2** using HARQ-**2** without bundling using the TFRE as shown in row **5** of FIG. **15**. With scheduled rank **1**, a new first data block may be transmitted over transmission/reception layers TL**1**/RL**1** using HARQ-**1** without bundling using the TFRE, and HARQ-**2** may remain unused during the TFRE as shown in row **7** of FIG. **15**.

In cases where the single data block fails F (rows **2**, **4**, **6**, and **8** of FIG. **15**) decoding (so that a NACK message is received), base station processor **101** may consider the reported rank, but base station processor **101** may schedule the downlink transmission using the reported rank or a different rank to maintain a HARQ process mapping to support the retransmission of the failed data block. As shown at rows **2**, **4**, and **6** of FIG. **15**, for example, if wireless terminal **200** reports a rank higher than that of the initial transmission (i.e., a reported rank of **2**, **3**, or **4** with an initial rank of **1**), base station processor **101** may allow scheduling of a higher rank transmission but not necessarily the rank reported/requested by wireless terminal **200**. As shown at rows **4** and **6** of FIG. **15**, if wireless terminal **200** reports/requests a rank of **3** or **2** after a failed rank **1** transmission/reception, base station processor **101** may schedule the reported/requested rank (i.e., rank **3** or **2**) because the HARQ-**1** is mapped to the first transmission/reception layer TL**1**/RL**1** without bundling for rank **1**, **2**, and **3** transmission/reception according to embodiments of FIG. **14**. As shown at row **2** of FIG. **15**, if wireless terminal **200** reports/requests a rank of **4** after a failed rank **1** transmission/reception, base station processor **101** may schedule a rank **3** transmission (higher than the previous rank **1** transmission) because a rank **3** transmission maintains the mapping of the first transmission/reception layer TL**1**/RL**1** to HARQ-**1** without bundling to support retransmission (in contrast to a rank **4** transmission that would bundle HARQ-**1**). If the reported rank is the same as the initial rank as shown in row **8** of FIG. **15**, the scheduled rank may remain unchanged so that the mapping of HARQ-**1** to transmission/reception layers TL**1**/RL**1** is unchanged and so that the failed data block may be retransmitted using the same HARQ-**1** mapping. More generally, if the reported rank is unchanged relative to the initial rank as shown in rows **7** and **8** of FIG. **15** the reported rank may be scheduled whether the initial data block(s) was(were) successfully decoded or not.

FIG. **16** illustrates base station processor **101** rank schedulings when an initial rank **2** downlink transmission is performed using HARQ-**1** mapped to first transmission/reception layers TL**1**/RL**1** (without bundling/sharing) and using HARQ-**2** mapped to second transmission/reception layers TL**2**/RL**2** (without bundling/sharing). Accordingly, the initial transmission includes a first data block transmitted/received using transmission/reception layers TL**1**/RL**1** and a second data block transmitted/received using transmission/reception layers TL**2**/RL**2**. The resulting ACK/NACK message for HARQ-**1** maps to only the first data block (i.e., an ACK message is generated if the first data block passes decoding at CD**1**, or a NACK message is generated if the single data block fails decoding at CD**1**), and the resulting ACK/NACK message for the HARQ-**2** process maps to only the second data block (i.e., an ACK message is generated if the second data block passes decoding at CD**2**, or a NACK message is generated if the second data block fails decoding at CD**2**).

In each case where both of the first and second data blocks pass P (i.e., rows **1**, **5**, **9**, and **13**) decoding (so that two ACK messages are received), base station processor **101** may schedule the rank recommended/requested by wireless terminal **200**, and new data NT may be transmitted in accordance with the UE reported rank as discussed above with respect to rows **1**, **3**, **5**, and **7** of FIG. **15**. In each case where wireless terminal **200** reports/recommends rank **2** that is the same as the initial rank (as in rows **9**, **10**, **11**, and **12** of FIG. **11**), base station processor **101** may maintain the same scheduled rank (i.e., rank **2**) regardless of the pass/fail status of the initially transmitted data blocks. The same rank **2** HARQ process mappings for HARQ-**1** and HARQ-**2** are maintained for the next transmission/retransmission regardless of the status P/F of the initial rank **2** transmission. Accordingly, retransmissions of one or both of the first and second data blocks (OT) may be supported using the same HARQ mappings, and/or new data blocks may be transmitted for either or both HARQ processes for which initial decoding passed.

When wireless terminal **200** reports a higher rank (i.e., rank **3** or rank **4**) and the second data block (mapped to HARQ-**2** without bundling/sharing) of the initial transmission fails F decoding resulting in a HARQ-**2** NACK message (as in rows **2**, **4**, **6**, and **8** of FIG. **16**), base station processor **101** may select rank **2** to maintain the same downlink transmission rank. The same rank **2** HARQ process mappings for HARQ-**1** and HARQ-**2** are thus maintained for the retransmission of the second data block using HARQ-**2** that failed and for the possible retransmission of the first data block using HARQ-**1** if it failed or the transmission of a new data block using HARQ-**1** if the initial first data block passed.

When wireless terminal **200** reports a higher rank (i.e., rank **3** or rank **4**), when the second data block (mapped to HARQ-**2** without bundling/sharing) of the initial transmission passes P decoding, and when the first data block (mapped to HARQ-**1** without bundling/sharing) of the initial transmission fails F

decoding resulting in a HARQ-1 NACK message (as in rows 3 and 7 of FIG. 16), base station processor 101 may select rank 3 (at rows 3 and 7 of FIG. 16) to maintain the same HARQ-1 mapping to transmission/reception layers TL/RL (without sharing/bundling) while allowing HARQ-2 to be mapped to transmission/reception layers TL2/RL2 and TL3/RL3 to allow transmission of two new data blocks NT using the HARQ-2 process. Stated in other words, a higher rank may be allowed even though the first data block failed because the mapping of HARQ-1 to transmission/reception layers TL1/RL1 (without sharing/bundling) is the same for both rank 2 and rank 3 transmissions. While the mapping of HARQ-2 is different for rank 2 and rank 3 transmissions, a same mapping of HARQ-2 is not required because the initial HARQ-2 data block passed. Accordingly, a higher data rate rank 3 transmission (allowing retransmission of the one HARQ-1 data packet that failed and 2 new HARQ-2 data packets) may be allowed while supporting the HARQ-1 retransmission.

At row 14 of FIG. 16, if the first data block (of HARQ-1) of the initial transmission passes (P), if the second data block (of HARQ-2) of the initial transmission fails (F), and wireless terminal 200 reports rank 1, base station processor 101 may schedule a rank two transmission to support transmission of a new data block over transmission/reception layers TL1/RL1 using HARQ-1 and retransmission of the second data block over transmission/reception layers TL2/RL2 using HARQ-2. At row 15 of FIG. 16, if the first data block (of HARQ-1) of the initial transmission fails (F), if the second data block (HARQ-2) of the initial transmission passes (P), and wireless terminal 200 reports rank 1, base station processor 101 may schedule a rank one transmission retransmitting the first data block of the initial transmission using HARQ-1 (without bundling/sharing) over transmission/reception layers TL1/RL. At row 16 of FIG. 16, if both of the first data block (HARQ-1) and the second data block (HARQ-2) of the initial transmission fail (F) and wireless terminal 200 reports rank 1, base station processor 101 may force a rank 2 transmission to maintain the mappings of HARQ-1 to transmission/reception layers TL1/RL1 and HARQ-2 to transmission/reception layers TL2/RL2 for retransmissions of both of the failed data blocks.

FIG. 17 illustrates base station processor 101 rank schedulings when an initial rank 3 downlink transmission is performed using HARQ-1 mapped to first transmission/reception layers TL1/RL1 (without bundling/sharing) and using HARQ-2 mapped to second and third transmission/reception layers TL2/TL2 and TL3/RL3 (with bundling/sharing). Accordingly, the initial transmission includes a first data block transmitted/received using transmission/reception layers TL1/RL1, a second data block transmitted/received using transmission/reception layers TL2/RL2, and a third data block transmitted/received using transmission/reception layers TL3/RL3. The resulting ACK/NACK message for HARQ-1 thus maps to the first data block (i.e., an ACK message is generated if the first data block passes decoding at CD1, or a NACK message is generated if the first data block fails decoding at CD1), and the resulting ACK/NACK message for the HARQ-2 process maps to the second and third data blocks (i.e. an ACK message is generated if both of the second and third data block pass decoding at CD2 and CD3, or a NACK message is generated if either of the second and/or third data blocks fail decoding at CD2 and/or CD3).

In cases where each of the first, second, and third data blocks pass decoding so that both HARQ-1 and HARQ-2 pass P (i.e., so two ACK messages are received), base station processor 101 may schedule the rank recommended/requested by wireless terminal 200 (as in rows 1, 5, 9, and 13 of FIG. 17), and new data NT may be transmitted in accordance with the UE reported rank as discussed above with respect to FIGS. 15 and 16. In each case where wireless terminal 200 reports a recommended/requested rank 3 that is the same as the initial rank (as in rows 5, 6, 7, and 8 of FIG. 13), base station processor 101 may maintain the same scheduled rank (i.e. rank 3). The same rank 3 HARQ process mappings for HARQ-1 and HARQ-2 are thus maintained for the next transmission/retransmission regardless of the status P/F of the initial rank 3 transmission. Accordingly, retransmission of the first data block (OT) of HARQ-1 and/or retransmission of the second and third data blocks (OT) of HARQ-2 may be supported using the same HARQ mappings, and/or new data blocks may be transmitted for either or both HARQ processes for which initial decoding passed.

When wireless terminal 200 reports a higher rank (i.e., rank 4) and the first data block (mapped to HARQ-1 without bundling/sharing) of the initial transmission fails F decoding resulting in a HARQ-1 NACK message (as in rows 3 and 4 of FIG. 17), base station processor 101 may maintain rank 3 to maintain the same rank 3 HARQ process mappings for HARQ-1 and HARQ-2. Accordingly, any needed retransmissions may be supported. When wireless terminal 200 reports a higher rank (i.e., rank 4) and the first data block (mapped to HARQ-1 without bundling/sharing) of the initial transmission passes decoding resulting in a HARQ-1 ACK message (as in rows 1 and 2 of FIG. 17), base station processor 101 may schedule rank 4 so that HARQ-1 is mapped to transmission/reception layers TL1/RL1 and TL4/RL4 and so that HARQ-2 is mapped to transmission/reception layers TL2/RL2 and TL3/RL3. Here the HARQ-2 mapping is unchanged between rank 3 and rank 4 to support retransmission of second and third data blocks mapped to HARQ-2 if needed as shown at row 2 of FIG. 17.

When wireless terminal 200 reports rank 2 and the second and third data blocks (mapped to HARQ-2 with sharing/bundling) pass decoding resulting in a HARQ-2 ACK message (as in rows 9 and 11 of FIG. 17), base station processor 101 may schedule rank 2 so that HARQ-1 is mapped to transmission/reception layers TL1/RL1 (without sharing/bundling) and so that HARQ-2 is mapped to transmission/reception layers TL2/RL2 (without sharing/bundling). Accordingly, a mapping of HARQ-1 to transmission/reception layers TL1/RL1 is the same for rank 2 and rank 3 downlink transmissions. Because both of the second and third data blocks of the initial HARQ-2 transmission passed decoding, retransmission using the HARQ-2 process is not required and remapping of the HARQ-2 process can occur without affecting any HARQ-2 retransmissions.

When wireless terminal 200 reports rank 2 and either or both of the second and third data blocks (mapped to HARQ-2 with sharing/bundling) fail decoding (F) resulting in a HARQ-2 NACK message (as in rows 10 and 12 of FIG. 17) base station processor 101 may continue scheduling rank 3 (as in rows 10 and 12 of FIG. 17) so that mappings of HARQ-1 and HARQ-2 remain unchanged (i.e., HARQ-1 maps to transmission/reception layers TL1/RL1 and HARQ-2 maps to transmission/reception layers TL2/RL2 and TL3/RL3). Accordingly, retransmissions of second and third data blocks of HARQ-2 may be supported, and retransmission of a first data block of HARQ-1 may be supported if needed (at row 12 of FIG. 17).

At rows 13 and 15 of FIG. 17, if the second and third data blocks (mapped to HARQ-2) of the initial transmission pass (P) and wireless terminal 200 reports rank 1, base station processor may schedule a rank 1 transmission supporting

transmission of new data or retransmission of old data using the first transmission/reception layers RL1/TL1. At rows **14** and **16** of FIG. **17**, if either of the second and/or third data blocks (mapped to HARQ-**2**) of the initial transmission fail (F) and wireless terminal **200** reports rank **1**, base station processor **101** may schedule/maintain rank **3** transmission to support retransmission of the second and/or third data blocks using transmission/reception layers RL**2**/TL**2** and RL**3**/TL**3** mapped to HARQ-**2**.

The table of FIG. **18** illustrates base station processor **101** rank schedulings when an initial rank **4** downlink transmission is performed using HARQ-**1** mapped to first and fourth transmission/reception layers TL**1**/RL**1** and TL**4**/RL**4** (with bundling/sharing) and using HARQ-**2** mapped to second and third transmission/reception layers TL**2**/RL**2** and TL**3**/RL**3** (with bundling/sharing). Accordingly, the initial transmission includes a first data block transmitted/received using transmission/reception layers TL**1**/RL**1**, a second data block transmitted/received using transmission/reception layers TL**2**/RL**2**, a third data block transmitted/received using transmission/reception layers TL**3**/RL**3**, and a fourth data block transmitted using transmission/reception layers TL**4**/RL**4**. The resulting ACK/NACK message for HARQ-**1** thus maps to the first and fourth data blocks (i.e., an ACK message is generated if both the first and fourth data blocks pass decoding at CD**1** and CD**4**, or a NACK message is generated if either or both of the first and fourth data blocks fail decoding at CD**1**/CD**4**), and the resulting ACK/NACK message for HARQ-**2** maps to the second and third data blocks (i.e., an ACK message is generated if both the second and third data blocks pass decoding at CD**2** and CD**3**, or a NACK message is generated if either or both of the second and third data blocks fail decoding at CD**2**/CD**3**).

In each case where all of the first, second, third and fourth data blocks pass decoding so that both HARQ-**1** and HARQ-**2** pass P (i.e., so two ACK messages are received), base station processor **101** may schedule the rank reported/requested by wireless terminal **200** (as in rows **1**, **5**, **9**, and **13** of FIG. **18**), and new data NT may be transmitted in accordance with the UE reported rank as discussed above with respect to FIGS. **15**, **16**, and **17**. In each case where wireless terminal **200** reports a recommended/requested rank **4** that is the same as the initial rank (as in rows **1**, **2**, **3**, and **4** of FIG. **18**), base station processor **101** may maintain the same scheduled rank (i.e., rank **4**). The same rank **4** HARQ process mappings for HARQ-**1** and HARQ-**2** are thus maintained for the next transmission/retransmission regardless of the status P/F of the initial rank **4** transmission. Accordingly, retransmissions of the first and fourth data blocks (OT) of HARQ-**1** and/or retransmission of the second and third data blocks (OT) of HARQ-**2** may be supported using the same HARQ mappings, and/or new data blocks may be transmitted for either or both HARQ processes for which initial decoding passed.

When wireless terminal **200** reports a lower rank (e.g., rank **3**, rank **2**, or rank **1**) and either or both of the first and fourth data blocks (mapped to HARQ-**1** with sharing/bundling) fail decoding F resulting in a HARQ-**1** NACK message (as in rows **7**, **8**, **11**, **12**, **15**, or **16** of FIG. **18**), base station processor **101** may continue scheduling rank **4** so that HARQ-**1** is mapped to the first and fourth transmission/reception layers TL**1**/RL**1** and TL**4**/RL**4** to support retransmission of the first and fourth data blocks. By continuing rank **4**. HARQ-**2** may continue to be mapped to transmission/reception layers TL**2**/RL**2** and TL**3**/RL**3** to support retransmission of the second and third data blocks (mapped to HARQ-**2** with sharing/bundling) if needed (e.g., at rows **8**, **12**, or **16** of FIG. **18**), or two new data blocks may be transmitted using HARQ-**2** (e.g., at rows **7**, **11**, or **15** of FIG. **18**).

When wireless terminal **200** reports rank **3** and the first data block (mapped to HARQ-**1** without sharing/bundling) passes decoding P resulting in a HARQ-**1** ACK message (as in rows **5** and **6** of FIG. **18**), base station processor **101** may scheduling rank **3** so that HARQ-**1** is mapped to the first transmission/reception layers TL**1**/RL**1** (without bundling/sharing), and so that HARQ-**2** is mapped to the second and third transmission/reception layers RL**2**/TL**2** and TL**3**/RL**3** (with bundling/sharing) to support retransmission of the second and third data blocks if needed (e.g., at row **6** of FIG. **18**).

When wireless terminal **200** reports rank **2** and any of the first, second, third and/or fourth data blocks fail decoding resulting in a HARQ-**1** NACK and/or a HARQ-**2** NACK (as in rows **10**, **11**, and/or **12**), base station processor **101** may schedule rank **4** so that HARQ-**1** is mapped to transmission/reception layers RL**1**/TL**1** and RL**4**/TL**4** (with bundling/sharing) and HARQ-**2** is mapped to transmission/reception layers RL**2**/TL**2** and RL**3**/TL**3** (with bundling/sharing). Accordingly, mappings of HARQ-**1** to transmission/reception layers TL**1**/RL**1** and TL**4**/RL**4** and HARQ-**2** to transmission/reception layers RL**2**/TL**2** and RL**3**/TL**3** are maintained to support retransmissions as needed.

When wireless terminal **200** reports rank **1** and any of the first, second, third, and/or fourth data blocks fail decoding (F) resulting in a HARQ-**1** NACK and/or a HARQ-**2** NACK message (as in rows **14**, **15**, and/or **16**), base station processor **101** may schedule rank **4** so that HARQ-**1** is mapped to transmission/reception layers RL**1**/TL**1** and RL**4**/TL**4** (with bundling/sharing) and HARQ-**2** is mapped to transmission/reception layers RL**2**/TL**2** and RL**3**/TL**3** (with bundling/sharing). Accordingly, mappings of HARQ-**1** to transmission/reception layers TL**1**/RL**1** and TL**4**/RL**4** and HARQ-**2** to transmission/reception layers RL**2**/TL**2** and RL**3**/TL**3** are maintained to support retransmissions as needed.

According to embodiments discussed above with respect to FIGS. **14-18** when an initial transmission/reception has a rank greater than 1 (e.g., rank **2**, **3**, or **4**) and both HARQ processes pass (i.e., both HARQ-**1** and HARQ-**2** generate ACK messages), base station processor **101** may select the rank reported/requested by wireless terminal **200** for a subsequent transmission to wireless terminal **100**. When an initial transmission/reception has a rank greater than 1 (e.g., rank **2**, **3**, or **4**) and both HARQ processes fail (i.e., HARQ-**1** and HARQ-**2** generate NACK messages), base station processor **101** may maintain the rank used for the initial transmission (regardless of the rank reported/requested by wireless terminal **200**) to support retransmission of data blocks corresponding to HARQ-**1** and HARQ-**2**.

If an initial transmission is a rank **2** transmission so that an initial data block transmitted/received over transmission/reception layers RL**2**/TL**2** and mapped to HARQ-**2** without bundling, and if HARQ-**2** generates a NACK due to failure decoding the initial data block, base station processor **101** may restrict the next transmission to rank **2** (regardless of the rank reported/requested by wireless terminal **200**) to support retransmission of the data block over transmission/reception layers RL**2**/TL**2** as shown in rows **2**, **4**, **6**, **8**, **10**, **12**, **14**, and **16** of FIG. **16** because no other rank (e.g., rank **1**, **3**, or **4**) supports non-bundled use of transmission/reception layers RL**2**/TL**2**. Stated in other words, if a data block is mapped to a HARQ process without bundling and the data block fails decoding, the same rank may be maintained for retransmission (regardless of the rank reported/requested by wireless terminal) if no other rank supports non-bundled transmission/reception using the same transmission/reception layer.

Using mappings of FIGS. **15-18** bundled transport blocks sharing a same HARQ process that fail decoding during an initial transmission may thus be retransmitted using the same transmission/reception layers bundled to the same HARQ process.

FIG. **19** is a flow chart illustrating operations of base station processor **101** and/or transceiver **109** communicating with a wireless terminal **200** according to some embodiments of present inventive concepts. More particularly, FIG. **19** illustrates base station operations with respect to a given instance of HARQ processes HARQ-**1** and HARQ-**2** identified by respective HARQ identifications H_a and H_b used to communicate with wireless terminal **200**. While not shown in FIG. **19**, other instances of HARQ processes HARQ-**1** and HARQ-**2** identified by other HARQ identifications may also be used for downlink transmissions from base station **100** to wireless terminal **200**. For example, different instances of HARQ processes HARQ-**1** and/or HARQ-**2** may be used in parallel to allow transmission using one instance while awaiting ACK/NACK feedback for another instance.

At block **1921**, base station processor **101** and/or transceiver **109** may wait until data is available for a current TFRE/TTI to be transmitted to wireless terminal **200**. When data is available for a current TFRE/TTI (e.g., new data for an initial transmission and/or previously transmitted data for a retransmission) at block **1921** and the instance of the HARQ process(es) have not been used for previous downlink transmission to wireless terminal **200** at block **1923**, processor **101** and/or transceiver **109** may receive channel state information from wireless terminal **200** at block **1934** including a reported/requested MIMO rank, a reported/requested precoding codebook index, a modulation/coding scheme, etc. If the instance of the HARQ process(es) has(have) not been used for a previous transmission at block **1923** (i.e., an initial transmission of data for the instance of the HARQ process(es)), processor **101** and/or transceiver **109** may select the MIMO rank for the current TFRE/TTI responsive to the reported/requested rank (i.e., the rank reported/requested by wireless terminal **200**) at block **1935**. At block **1931**, base station processor **101** and/or transceiver **109** may transmit downlink (DL) signaling to wireless terminal **200** with the downlink signaling identifying the MIMO rank selected/scheduled for the current TFRE/TTI, and at block **1933**, processor **101** and/or transceiver **109** may transmit the data (as one or more transport data blocks) in accordance with the selected MIMO rank (i.e., the MIMO rank scheduled by processor **101** for the downlink TFRE/TTI).

Wireless terminal **200** may then transmit one HARQ ACK/NACK message for HARQ-**1** for a rank **1** TFRE/TTI, or a first HARQ ACK/NACK message for HARQ-**1** and a second HARQ ACK/NACK message for HARQ-**2** for a rank **2** TFRE/TTI, for a rank **3** TFRE/TTI, or for a rank **4** TFRE/TTI to indicate success/failure decoding data of the TFRE/TTI. Once initial data has been transmitted for a given instance of a HARQ process, selection of MIMO rank(s) for a subsequent TFRE(s)/TTI(s) may be based on a reported MIMO rank (requested by the wireless terminal) and/or a HARQ ACK/NACK message(s) received from the wireless terminal as discussed in greater detail below with respect to blocks **1921**, **1923**, **1925**, **1927**, **1929**, **1931**, and **1933**.

As discussed above, a first MIMO downlink communication may be transmitted to wireless terminal **200** according to a first/initial MIMO rank at block **1933**. At block **1921**, processor **101** may determine that data is available for a next/subsequent TFRE/TTI. For example, new data may be available for initial transmission, and/or previously transmitted data may be available for retransmission (e.g., responsive to a NACK message from the previous TFRE/TTI). If the TFRE/TTI is a next/subsequent TFRE/TTI for a given instance of a HARQ process(es) at block **1923**, processor **101** and/or transceiver **109** may receive a report from the wireless terminal **200** identifying a reported MIMO rank at block **1925**. At block **1927**, processor **101** and/or transceiver **109** may receive at least one HARQ ACK/NACK message from the wireless terminal **200** corresponding to the previous MIMO downlink communication using the given instance of the HARQ process(es). At block **1929**, processor **101** and/or transceiver **109** may select a second MIMO rank (e.g., referred to as the selected and/or scheduled MIMO rank) for subsequent MIMO downlink communication responsive to the reported MIMO rank and responsive to the at least one HARQ ACK/NACK message. The second MIMO downlink communication may then be transmitted to the wireless terminal **200** according to the second MIMO rank (selected responsive to the reported MIMO rank and the HARQ ACK/NACK message/messages from the previous TFRE/TTI for the given instance of the HARQ process/processes).

More particularly, the MIMO rank may be selected at block **1929** in accordance with the tables of FIGS. **10-13** or in accordance with the tables of FIGS. **15-18**. If the first (previous) MIMO rank is greater than rank **1** (so that two HARQ ACK/NACK messages are received for the first/previous TFRE/TTI) and the first/previous MIMO rank and the reported MIMO rank are different, for example, the second/subsequent MIMO rank may be selected at block **1929** to be different than the reported MIMO rank if each of the first and second HARQ ACK/NACK messages is a NACK message (e.g., in accordance with: rows **4**, **8**, **16** of FIG. **11**; rows **4**, **8**, **16**, of FIG. **16**; rows **8**, **12**, and **16** of FIG. **12**; rows **4**, **12**, and **16** of FIG. **17**; rows **8**, **12**, and **16** of FIG. **13**; and/or rows **8**, **12**, and **16** of FIG. **18**). The second MIMO rank may be selected to be the same as the reported MIMO rank at block **1929**, for example, responsive to all of the HARQ ACK/NACK messages corresponding to the first MIMO downlink communication being ACK messages indicating successful decoding of all data blocks of the first MIMO downlink communication (e.g. in accordance with: rows **1**, **3**, **5**, and **7** of FIGS. **10** and **15**; rows **1**, **5**, **9**, and **13** of FIGS. **11-13** and **16-18**).

If the first MIMO rank is rank **4** and the reported MIMO rank is less than rank **3**, the second MIMO rank may be selected at block **1929** to be different than the reported MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message (e.g., in accordance with: rows **10-12** and **14-16** of FIGS. **13** and **18**).

If the first MIMO rank is rank **2** and the reported MIMO rank is rank **4**, the second MIMO rank may be selected to be different than the reported MIMO rank and different than the first MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message (e.g., in accordance with: rows **10-12** and **14-16** of FIGS. **13** and **18**).

If the first MIMO rank is at least 2 and the reported MIMO rank is different than the first MIMO rank, the second MIMO rank may be selected at block **1929** to be the same as the reported MIMO rank responsive to the first and second HARQ ACK/NACK messages being ACK messages (e.g. in accordance with: rows **1**, **3**, **5**, and **7** of FIGS. **10** and **15**; and/or rows **1**, **5**, **9**, and **13** of FIGS. **11-13** and **16-18**), and the second MIMO rank to be selected at block **1929** to be the same as first MIMO rank responsive to both of the first and second HARQ ACK/NACK messages being NACK messages (e.g., in accordance with: rows **4**, **8**, **16** of FIGS. **11** and

16: rows 8, 12, and 16 of FIG. 12; rows 4, 12, and 16 of FIG. 17; rows 8, 12, and 16 of FIG. 13; and/or rows 8, 12, and 16 of FIG. 18).

Operations of FIG. 19 may be performed in a base station wherein antenna arrays 117 and 217 each include four MIMO antenna elements to support up to four parallel MIMO transmission streams/layers (i.e., up to rank 4). For a rank 1 MIMO downlink communication, transmitting the first MIMO downlink communication may include transmitting a first data block over a first MIMO layer TL1 for the first/previous TFRE/TTI, and receiving at least one HARQ ACK/NACK message may include receiving a first HARQ ACK/NACK message corresponding to the first data block. For a rank 2 MIMO downlink communication, transmitting the first/previous MIMO downlink communication may include transmitting first and second data blocks over respective first and second MIMO transmission layers TL1 and TL2 during the first/previous TFRE/TTI, and receiving at least one HARQ ACK/NACK message include receiving first and second HARQ ACK/NACK messages respectively corresponding to the first and second data blocks. For a rank 3 MIMO downlink communication, transmitting the first/previous MIMO downlink communication may include transmitting first, second, and third data blocks over respective first, second, and third MIMO transmission layers TL1, TL2, and TL3 during the first/previous TFRE/TTI, and receiving at least one HARQ ACK/NACK message may include receiving a first HARQ ACK/NACK message corresponding to the first data block and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks. For a rank 4 MIMO downlink communication, transmitting the first/previous MIMO downlink communication may include transmitting first, second, third, and fourth data blocks over respective first, second, third, and fourth MIMO layers TL1, TL2, TL3, and TL4 during the first/previous TFRE/TTI, and receiving at least one HARQ ACK/NACK message may include receiving a first HARQ ACK/NACK message corresponding to the first and fourth data blocks and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks.

If base station (Node B) 100 uses the same rank as that reported/recommended by wireless terminal (UE) 200, situations may occur where retransmission is not possible for two transport blocks belonging to the same HARQ process ID, and significant delays in scheduling retransmissions of these two transport blocks may occur causing the RLC (Radio Link Protocol) timer to expire before retransmission occurs. Higher layers may be required to restart the transmission process for the two transport blocks, potentially causing significant interruptions and/or delaying sensitive applications. By selecting MIMO ranks responsive to both UE reported/recommended rank and ACK/NACK message feedback as disclosed herein, these potential problems may be reduced and/or avoided.

A HARQ process (e.g., HARQ-1 or HARQ-2) and a respective HARQ identification (e.g. H_a or H_b) may be used to support downlink transmissions/retransmissions from base station 100 to wireless terminal 200, and two HARQ processes and respective HARQ identifications may support HARQ ACK/NACK signaling for 4 antenna MIMO systems supporting up to 4 layer/stream downlink transmissions (and/or higher antenna systems supporting higher rank/layer transmissions). For rank 1 transmissions, first HARQ process/identification HARQ-1/H_a maps to a first transmission/reception layer (e.g., including TB1, CE1, IM1, DM1, SB1, and/or CD1). For rank 2 transmissions, first HARQ process/identification HARQ-1/H_a maps to the first transmission/reception layer, and second HARQ process/identification HARQ-2/H_a maps to a second transmission/reception layer (e.g., including TB2, CE2, IM2, DM2, SB2, and/or CD2). For rank 3 transmissions, first HARQ process/identification HARQ-1/H_a maps to the first transmission/reception layer, and second HARQ process/identification HARQ-2/H_b maps to the second transmission/reception layer and to a third transmission/reception layers (e.g., including TB3, CE3, IM3, DM3, SB3, and/or CD3). For rank 4 transmissions, first HARQ process/identification HARQ-1/H_a maps to the first transmission/reception layer and to a fourth transmission/reception layer (e.g., including TB4, CE4, IM4, DM4, SB4, and/or CD4), and second HARQ process/identification HARQ-2/H_b maps to the second and third transmission/reception layers.

Because of the delay between base station 100 transmitting a first data block(s) to wireless terminal 200 during a first downlink TTI/TFRE and receiving a HARQ ACK/NACK response(s) for the first data block(s) from wireless terminal 200, second data block(s) may be transmitted to wireless terminal 200 during a second downlink TTI/TFRE before receiving the HARQ ACK/NACK response(s) for the first data block(s). Accordingly, HARQ process identifications may be used by base station 100 to distinguish between different HARQ ACK/NACK responses for different data blocks of different downlink TTIs/TFREs transmitted to the same wireless terminal 200. Stated in other words, HARQ process identifications may be used to match HARQ ACK/NACK responses with the appropriate data block(s) and TTI/TFRE. HARQ process identifications may also be used by wireless terminal 100 to match the data block/blocks with the appropriate soft bits from respective soft buffer/buffers.

A same HARQ process identification may thus be used for the initial transmission and for each retransmission of a data block/blocks to wireless terminal 200 until either the data block/blocks is/are successfully received/decoded by wireless terminal 200 (as indicated by an ACK) or until a maximum allowed number of retransmissions have occurred. Once the data block/blocks have been successfully received/decoded or a maximum number of retransmissions has occurred, the HARQ process identification for the data block/blocks may be destroyed, meaning that the HARQ process identification may then be reused for a new data block/blocks.

Accordingly to some embodiments, a HARQ process identification may be selected from one of eight values (e.g., 1, 2, 3, 3, 5, 6, 7, or 8). For rank 1, 2, and 3 downlink transmissions to wireless terminal 200, HARQ process identification H_a is mapped to a first HARQ process HARQ-1 for layer 1 transmission using the first transmission/reception layer (e.g., including TB1, CE1, IM1, DM1, SB1, and/or CD1). For rank 4 downlink transmissions to wireless terminal, HARQ process identification H_a is mapped to the first HARQ process HARQ-1 for layer 1 and 4 transmissions using the first and fourth transmission/reception layers. For rank 2 downlink transmissions to wireless terminal 200, HARQ process identification H_b is mapped to second HARQ process HARQ-2 for layer 2 transmission using the second transmission/reception layer. For rank 3 and 4 downlink transmissions to wireless terminal. HARQ process identification H_b is mapped to the second HARQ process HARQ-2 for layer 2 and 3 transmissions using the second and third transmission/reception layers. Accordingly, HARQ process HARQ-1 and identification H_a are used for rank 1, 2, 3, and 4 transmissions, and HARQ process HARQ-2 and identification H_b are used for rank 2, 3, and 4 transmissions.

For an initial rank **1** transmission of a data block, a currently unused identification value (e.g., selected from **1-8**) is assigned to H_a for HARQ process HARQ-**1**, and H_a is used to identify the instance of HARQ-**1** that is applied to transmissions/retransmissions of the layer **1** data block and that is applied to HARQ ACK/NACK responses corresponding to the layer **1** data block.

For an initial rank **2**, **3**, or **4** transmission of data blocks using both HARQ processes HARQ-**1** and HARQ-**2** during a same TTI/TFRE, a currently unused identification value (e.g., selected from **1-8**) is assigned to H_a for HARQ process HARQ-**1**, and another identification value is assigned to H_b for process HARQ-**2** (e.g., as a function of H_a). Accordingly. H_a is used to identify the instance of HARQ-**1** that is applied to transmissions/retransmissions of layer **1**/**4** data block/blocks (for layer **1** and/or **4** transmissions/retransmissions) and that is applied to HARQ ACK/NACK responses corresponding to the layer **1**/**4** data blocks, and H_b is used to identify the instance of HARQ-**2** that is applied to transmissions/retransmissions of the layer **2**/**3** data block/blocks (for layer **2** and/or **3** transmissions/retransmissions) and that is applied to HARQ ACK/NACK responses corresponding to the layer **2**/**3** data block/blocks.

According to some embodiments, HARQ process identification H_b may be assigned as a function of HARQ process identification H_a. With eight different HARQ process identification values from one to eight, for example, identification H_b may be assigned according to the following formula:

$$H_b=(H_a+N/2)\bmod(N),$$

where N is the number of HARQ processes (e.g., two for HARQ-**1** and HARQ-**2**) as configured by higher layers andor by the radio network controller. With two HARQ processes and eight different HARQ process identification values, identification H_b may be selected as a function of H_a according to the following table:

H_a	H_b
1	5
2	6
3	7
4	8
5	1
6	2
7	3
8	4

Accordingly, only one of the HARQ process identifications (e.g., H_a) may need to be transmitted between base station **100** and wireless terminal **200**, with the other HARQ process identification (e.g., H_b) being derived at the receiving device using H_a.

If the Node B (base station) schedules three transport blocks in any transmission (i.e., rank **3**), for retransmissions, the second transport block and the third transport block are retransmitted with the same HARQ process identifier (that was shared by the second and third transport blocks for the initial transmission) as discussed above. If the Node B schedules four transport blocks in any transmission, for retransmissions, the primary transport block and the fourth transport block are re-transmitted with the same HARQ process identifier (that was shared by the primary and fourth transport blocks for the initial transmission), and the second and third transport blocks are re-transmitted with the same HARQ process identifier (that was shared by the second and third transport blocks for the initial transmission), as discussed above.

Acronyms/Abbreviations

Tx Transmitter

HSDPA High Speed Downlink Packet Access

HARQ Hybrid Automatic Repeat Request

CRC Cyclic Redundancy Check

NAK/NACK Non-Acknowledgment or Negative-Acknowledgment

ACK Acknowledgment

CC Chase Combining

IR Incremental Redundancy

UE User Equipment or Wireless Terminal

CQI Channel Quality Information

MMSE Minimum Mean Square Error

TTI Transmit Time Interval

PCI Precoding Control Index

In the above-description of various embodiments of present inventive concepts, it is to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of present inventive concepts. Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which present inventive concepts belong. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense expressly so defined herein.

When an element is referred to as being "connected", "coupled", "responsive", or variants thereof to another element, it can be directly connected, coupled, or responsive to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected", "directly coupled", "directly responsive", or variants thereof to another element, there are no intervening elements present. Like numbers refer to like elements throughout. Furthermore, "coupled", "connected", "responsive", or variants thereof as used herein may include wirelessly coupled, connected, or responsive. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. Well-known functions or constructions may not be described in detail for brevity and/or clarity. The term "and/or" includes any and all combinations of one or more of the associated listed items.

As used herein, the terms "comprise", "comprising", "comprises", "include", "including", "includes", "have", "has", "having", or variants thereof are open-ended, and include one or more stated features, integers, elements, steps, components or functions but does not preclude the presence or addition of one or more other features, integers, elements, steps, components, functions or groups thereof. Furthermore, as used herein, the common abbreviation "e.g.", which derives from the Latin phrase "exempli gratia," may be used to introduce or specify a general example or examples of a previously mentioned item, and is not intended to be limiting of such item. The common abbreviation "i.e.", which derives from the Latin phrase "id est." may be used to specify a particular item from a more general recitation.

It will be understood that although the terms first, second, third, etc. may be used herein to describe various elements/operations, these elements/operations should not be limited by these terms. These terms are only used to distinguish one element/operation from another element/operation. Thus a first element/operation in some embodiments could be termed a second element/operation in other embodiments

without departing from the teachings of present inventive concepts. The same reference numerals or the same reference designators denote the same or similar elements throughout the specification.

Example embodiments are described herein with reference to block diagrams and/or flowchart illustrations of computer-implemented methods, apparatus (systems and/or devices) and/or computer program products. It is understood that a block of the block diagrams and/or flowchart illustrations, and combinations of blocks in the block diagrams and/or flowchart illustrations, can be implemented by computer program instructions that are performed by one or more computer circuits. These computer program instructions may be provided to a processor circuit of a general purpose computer circuit, special purpose computer circuit, and/or other programmable data processing circuit to produce a machine, such that the instructions, which execute via the processor of the computer and/or other programmable data processing apparatus, transform and control transistors, values stored in memory locations, and other hardware components within such circuitry to implement the functions/acts specified in the block diagrams and/or flowchart block or blocks, and thereby create means (functionality) and/or structure for implementing the functions/acts specified in the block diagrams and/or flowchart block(s).

These computer program instructions may also be stored in a tangible computer-readable medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable medium produce an article of manufacture including instructions which implement the functions/acts specified in the block diagrams and/or flowchart block or blocks.

A tangible, non-transitory computer-readable medium may include an electronic, magnetic, optical, electromagnetic, or semiconductor data storage system, apparatus, or device. More specific examples of the computer-readable medium would include the following: a portable computer diskette, a random access memory (RAM) circuit, a read-only memory (ROM) circuit, an erasable programmable read-only memory (EPROM or Flash memory) circuit, a portable compact disc read-only memory (CD-ROM), and a portable digital video disc read-only memory (DVD/BlueRay).

The computer program instructions may also be loaded onto a computer and/or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer and/or other programmable apparatus to produce a computer-implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions/acts specified in the block diagrams and/or flowchart block or blocks. Accordingly, embodiments of present inventive concepts may be embodied in hardware and/or in software (including firmware, resident software, micro-code, etc.) that runs on a processor such as a digital signal processor, which may collectively be referred to as "circuitry," "a module" or variants thereof.

It should also be noted that in some alternate implementations, the functions/acts noted in the blocks may occur out of the order noted in the flowcharts. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved. Moreover, the functionality of a given block of the flowcharts and/or block diagrams may be separated into multiple blocks and/or the functionality of two or more blocks of the flowcharts and/or block diagrams may be at least partially integrated. Finally, other blocks may be added/inserted between the blocks that are illustrated, and/or blocks/operations may be omitted without departing from the scope of present inventive concepts. Moreover, although some of the diagrams include arrows on communication paths to show a primary direction of communication, it is to be understood that communication may occur in the opposite direction to the depicted arrows.

Many different embodiments have been disclosed herein, in connection with the above description and the drawings. It will be understood that it would be unduly repetitious and obfuscating to literally describe and illustrate every combination and subcombination of these embodiments. Accordingly, the present specification, including the drawings, shall be construed to constitute a complete written description of various example combinations and subcombinations of embodiments and of the manner and process of making and using them, and shall support claims to any such combination or subcombination.

Many variations and modifications can be made to the embodiments without substantially departing from the principles of present inventive concepts. All such variations and modifications are intended to be included herein within the scope of present inventive concepts. Accordingly, the above disclosed subject matter is to be considered illustrative, and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other embodiments, which fall within the spirit and scope of present inventive concepts. Thus, to the maximum extent allowed by law, the scope of the present invention is to be determined by the broadest permissible interpretation of the following claims, and shall not be restricted or limited by the foregoing detailed description.

That which is claimed is:

1. A method of operating a wireless network node, the method including:

transmitting a first multiple-input-multiple-output (MIMO) downlink communication to a wireless terminal according to a first MIMO rank, wherein the first MIMO rank defines a number of parallel MIMO transmission streams transmitted to the wireless terminal during the first MIMO downlink communication;

receiving a report from the wireless terminal identifying a reported MIMO rank, wherein the reported MIMO rank defines a recommendation for a number of parallel MIMO transmission streams to be transmitted to the wireless terminal during a second MIMO downlink communication;

receiving at least one Hybrid Automatic Repeat Request (HARQ) acknowledge/non-acknowledge (ACK/NACK) message from the wireless terminal corresponding to the first MIMO downlink communication;

selecting a second MIMO rank for the second MIMO downlink communication responsive to the at least one HARQ ACK/NACK message, wherein the second MIMO rank defines a number of parallel MIMO transmission streams to be transmitted to the wireless terminal during the second MIMO downlink communication, wherein selecting the second MIMO rank comprises selecting the second MIMO rank to be different than the reported MIMO rank responsive to at least one of the HARQ ACK/NACK messages; and

transmitting the second MIMO downlink communication to the wireless terminal according to the second MIMO rank.

2. The method according to claim **1** wherein selecting comprises selecting the second MIMO rank for the second

MIMO downlink communication responsive to the reported MIMO rank and responsive to the at least one HARQ ACK/NACK message.

3. The method according to claim 1 wherein the first MIMO rank is greater than rank 1 so that the number of parallel MIMO transmission streams transmitted to the wireless terminal during the first MIMO downlink communication is greater than 1, wherein receiving at least one HARQ ACK/NACK message includes receiving first and second HARQ ACK/NACK messages, wherein the first MIMO rank and the reported MIMO rank are different so that the number of parallel MIMO transmission streams recommended for transmission to the wireless terminal during the second MIMO downlink communication is different than the number of parallel MIMO transmission streams transmitted to the wireless terminal during the first MIMO downlink communication, wherein selecting the second MIMO rank comprises selecting the second MIMO rank to be different than the reported MIMO rank responsive to each of the first and second HARQ ACK/NACK messages being a NACK message so that the number of parallel MIMO transmission streams transmitted to the wireless terminal during the second MIMO downlink communication is different than the number of parallel MIMO transmission streams defined by the reported MIMO rank received in the report from the wireless terminal.

4. The method according to claim 1 wherein transmitting the first and second MIMO downlink communications comprises transmitting the first and second MIMO downlink communications from the wireless network node using a four antenna MIMO antenna array supporting up to four parallel MIMO transmission streams.

5. The method according to claim 4,

wherein the first MIMO rank is 2,

wherein transmitting the first MIMO downlink communication comprises transmitting first and second data blocks over respective first and second MIMO transmission streams, and

wherein receiving at least one HARQ ACK/NACK message comprises receiving first and second HARQ ACK/NACK messages respectively corresponding to the first and second data blocks.

6. The method according to claim 4,

wherein the first MIMO rank is 3,

wherein transmitting the first MIMO downlink communication comprises transmitting first, second, and third data blocks over respective first, second, and third MIMO transmission streams, and

wherein receiving at least one HARQ ACK/NACK message comprises receiving a first HARQ ACK/NACK message corresponding to the first data block and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks.

7. The method according to claim 4,

wherein the first MEMO rank is 4,

wherein transmitting the first MIMO downlink communication comprises transmitting first, second, third, and fourth data blocks over respective first, second, third, and fourth MIMO transmission streams, and

wherein receiving at least one HARQ ACK/NACK message comprises receiving a first HARQ ACK/NACK message corresponding to the first and fourth data blocks and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks.

8. The method according to claim 1 wherein the first MIMO rank is rank 4, wherein the at least one HARQ ACK/NACK message comprises first and second HARQ ACK/NACK messages corresponding to the first MIMO downlink communication, wherein the reported MIMO rank is less than rank 3, and wherein selecting the second MIMO rank comprises selecting the second MIMO rank to be different than the reported MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message.

9. The method according to claim 1 wherein the first MIMO rank is rank 2, wherein the at least one HARQ ACK/NACK message comprises first and second HARQ ACK/NACK messages corresponding to the first MIMO downlink communication, wherein the reported MIMO rank is rank 4, and wherein selecting the second MIMO rank comprises selecting the second MIMO rank to be different than the reported MIMO rank and different than the first MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message.

10. The method according to claim 4,

wherein the first MIMO rank is 1,

wherein transmitting the first MIMO downlink communication comprises transmitting a first data block over a first MIMO transmission stream, and

wherein receiving at least one HARQ ACK/NACK message comprises receiving a first HARQ ACK/NACK message corresponding to the first data block.

11. The method according to claim 3 wherein selecting the second MIMO rank comprises selecting the second MIMO rank to maintain a HARQ process mapping for retransmission of each data block of the first MIMO downlink communication for the second MIMO downlink communication.

12. A wireless network node comprising:

a transceiver configured to transmit and/or receive communications over a wireless channel; and

a processor coupled to the transceiver, wherein the processor is configured to transmit a first multiple-input-multiple-output (MIMO) downlink communication through the transceiver to a wireless terminal according to a first MIMO rank wherein the first MIMO rank defines a number of parallel MIMO transmission streams transmitted to the wireless terminal during the first MIMO downlink communication, to receive at least one Hybrid Automatic Repeat Request (HARQ) acknowledge/non-acknowledge (ACK/NACK)—message from the wireless terminal through the transceiver corresponding to the first MIMO downlink communication, to receive a report from the wireless terminal through the transceiver identifying a reported MIMO rank wherein the reported MIMO rank defines a recommendation for a number of parallel MIMO transmission streams to be transmitted to the wireless terminal during a second MIMO downlink communication, to select a second MIMO rank for the second MIMO downlink communication to be different than the reported MIMO rank responsive to at least one of the HARQ ACK/NACK messages being a NACK message wherein the second MIMO rank defines a number of parallel MIMO transmission streams to be transmitted to the wireless terminal during the second MIMO downlink communication, and to transmit the second MIMO downlink communication through the transceiver to the wireless terminal according to the second MIMO rank.

13. The wireless network node according to claim 12 wherein the processor is configured to select the second MIMO rank for the second MIMO downlink communication responsive to the reported MIMO rank and responsive to the at least one HARQ ACK/NACK message.

14. The wireless network node according to claim 12 wherein the first MIMO rank is greater than rank 1 so that the

number of parallel MIMO transmission streams transmitted to the wireless terminal during the first MIMO downlink communication is greater than 1, wherein receiving at least one HARQ ACK/NACK message includes receiving first and second HARQ ACK/NACK messages, wherein the first MIMO rank and the reported MIMO rank are different so that the number of parallel MIMO transmission streams recommended for transmission to the wireless terminal during the second MIMO downlink communication is different than the number of parallel MIMO transmission streams transmitted to the wireless terminal during the first MIMO downlink communication, wherein the processor is configured to select the second MIMO rank to be different than the reported MIMO rank responsive to each of the first and second HARQ ACK/NACK messages being a NACK message so that the number of parallel MIMO transmission streams transmitted to the wireless terminal during the second MIMO downlink communication is different than the number of parallel MIMO transmission streams defined by the reported MIMO rank received in the report from the wireless terminal.

15. The wireless network node according to claim **12** wherein the transceiver is configured to transmit the first and second MIMO downlink communications using a four antenna MIMO antenna array supporting up to four parallel MIMO transmission streams.

16. The wireless network node according to claim **15**, wherein the first MIMO rank is **2**,

wherein the processor is configured to transmit the first MIMO downlink communication through the transceiver by transmitting first and second data blocks over respective first and second MIMO transmission streams, and

wherein the processor is configured to receive at least one HARQ ACK/NACK message through the transceiver by receiving first and second HARQ ACK/NACK messages respectively corresponding to the first and second data blocks.

17. The wireless network node according to claim **15**, wherein the first MIMO rank is **3**,

wherein the processor is configured to transmit the first MIMO downlink communication through the transceiver by transmitting first, second, and third data blocks over respective first, second, and third MIMO transmission streams, and

wherein the processor is configured to receive at least one HARQ ACK/NACK message through the transceiver by receiving a first HARQ ACK/NACK message corresponding to the first data block and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks.

18. The wireless network node according to claim **15**, wherein the first MIMO rank is **4**,

wherein the processor is configured to transmit the first MIMO downlink communication through the transceiver by transmitting first, second, third, and fourth data blocks over respective first, second, third, and fourth MIMO transmission streams, and

wherein the processor is configured to receive at least one HARQ ACK/NACK message through the transceiver by receiving a first HARQ ACK/NACK message corresponding to the first and fourth data blocks and receiving a second HARQ ACK/NACK message corresponding to the second and third data blocks.

19. The wireless network node according to claim **12** wherein the first MIMO rank is rank **4**, wherein the at least one HARQ ACK/NACK message comprises first and second HARQ ACK/NACK messages corresponding to the first MIMO downlink communication, wherein the reported MIMO rank is less than rank **3**, and wherein the processor is configured to select the second MIMO rank to be different than the reported MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message.

20. The wireless network node according to claim **12** wherein the first MIMO rank is rank **2**, wherein the at least one HARQ ACK/NACK message comprises first and second HARQ ACK/NACK messages corresponding to the first MIMO downlink communication, wherein the reported MIMO rank is rank **4**, and wherein the processor is configured to select the second MIMO rank to be different than the reported MIMO rank and different than the first MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message.

21. The wireless network node according to claim **15**, wherein the first MIMO rank is **1**, wherein the processor is configured to transmit the first MIMO downlink communication through the transceiver by transmitting a first data block over a first MIMO transmission stream, and wherein the processor is configured to receive at least one HARQ ACK/NACK message through the transceiver by receiving a first HARQ ACK/NACK message corresponding to the first data block.

22. The wireless network node according to claim **14** wherein the processor is configured to select the second MIMO rank to maintain a HARQ process mapping for retransmission of each data block of the first MIMO downlink communication for the second MIMO downlink communication.

23. The method of claim **1** wherein the first MIMO rank defines a first number of MIMO transmission streams transmitted to the wireless terminal during the first MIMO downlink communication, wherein the second MIMO rank defines a second number of MIMO transmission streams transmitted to the wireless terminal during the second MIMO downlink communication, and wherein selecting comprises selecting the second MIMO rank based on the reported MIMO rank and based on the at least one HARQ ACK/NACK message.

24. The wireless network node of claim **12** wherein the first MIMO rank defines a first number of MIMO transmission streams transmitted to the wireless terminal during the first MIMO downlink communication, wherein the second MIMO rank defines a second number of MIMO transmission streams transmitted to the wireless terminal during the second MIMO downlink communication, and wherein the processor is configured to select the second MIMO rank based on the reported MIMO rank and based on the at least one HARQ ACK/NACK message.

25. The method according to claim **5** wherein the reported MIMO rank is rank **4**, wherein selecting the second MIMO rank comprises selecting the second MIMO rank to be different than the reported MIMO rank and different than the first MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message, and wherein transmitting the second MIMO downlink communication comprises retransmitting the first data block over the first MIMO transmission stream.

26. The wireless network node according to claim **16** wherein the reported MIMO rank is rank **4**, wherein the processor is configured to select the second MIMO rank to be different than the reported MIMO rank and different than the first MIMO rank responsive to at least one of the first and second HARQ ACK/NACK messages being a NACK message, and wherein the processor is configured to retransmit

the first data block over the first MIMO transmission stream when transmitting the second MIMO downlink communication.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,325,397 B2
APPLICATION NO. : 13/885044
DATED : April 26, 2016
INVENTOR(S) : Jonsson et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On Title Page 2, in Item (56), under "OTHER PUBLICATIONS", in Column 2, Line 33, delete "Physcial" and insert -- Physical --, therefor.

In the Specification

In Column 1, Line 8, delete "PCT/Sep2013/" and insert -- PCT/SE2013/ --, therefor.

In Column 6, Line 47, delete "is illustrates" and insert -- illustrates --, therefor.

In Column 8, Line 54, delete "Si" and insert -- S1 --, therefor.

In Column 9, Lines 14-15, delete "an liquid" and insert -- a liquid --, therefor.

In Column 10, Lines 35, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 10, Lines 42-43, delete "combined." and insert -- combined, --, therefor.

In Column 11, Line 11, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 12, Line 13, delete "herein" and insert -- herein, --, therefor.

In Column 12, Line 15, delete "101" and insert -- 101, --, therefor.

In Column 13, Line 16, delete "CW1." and insert -- CW1, --, therefor.

In Column 13, Line 25, delete "and/or" and insert -- and/or CE4 --, therefor.

In Column 13, Line 30, delete "TF" and insert -- TFRE. --, therefor.

Signed and Sealed this
Twenty-fifth Day of October, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

In Column 15, Line 26, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 15, Line 34, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 15, Line 50, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 16, Line 29, delete "TB3." and insert -- TB3, --, therefor.

In Column 16, Line 44, delete "200" and insert -- 200, --, therefor.

In Column 18, Line 39, delete "b3'-j" and insert -- b3'-j, --, therefor.

In Column 18, Line 40, delete "B2'." and insert -- B2', --, therefor.

In Column 20, Line 28, delete "CD" and insert -- CD1 --, therefor.

In Column 21, Line 11, delete "6 one" and insert -- 6, one --, therefor.

In Column 21, Line 33, delete "(i.e." and insert -- (i.e., --, therefor.

In Column 21, Line 35, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 22, Line 65, delete "ANK/NACK" and insert -- ACK/NACK --, therefor.

In Column 23, Line 42, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 23, Line 49, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 24, Line 53, delete "FIG. 8B" and insert -- FIG. 8B, --, therefor.

In Column 27, Line 19, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 27, Line 27, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 29, Line 20, delete "5:" and insert -- 5; --, therefor.

In Column 29, Line 48, delete "process." and insert -- process, --, therefor.

In Column 30, Line 45, delete "1)" and insert -- 1), --, therefor.

In Column 31, Line 58, delete "(i.e." and insert -- (i.e., --, therefor.

In Column 32, Line 9, delete "4)" and insert -- 4), --, therefor.

In Column 33, Line 46, delete "(i.e." and insert -- (i.e., --, therefor.

In Column 33, Line 64, delete "(i.e." and insert -- (i.e., --, therefor.

In Column 38, Line 42, delete "FIG. 14" and insert -- FIG. 14, --, therefor.

In Column 39, Line 9, delete "4:" and insert -- 4; --, therefor.

In Column 39, Line 23, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 40, Line 41, delete "TTI/TFRE" and insert -- TTI/TFRE, --, therefor.

In Column 42, Line 11, delete "15" and insert -- 15, --, therefor.

In Column 43, Line 60, delete "(i.e." and insert -- (i.e., --, therefor.

In Column 44, Line 8, delete "(i.e." and insert -- (i.e., --, therefor.

In Column 44, Line 54, delete "17)" and insert -- 17), --, therefor.

In Column 45, Line 63, delete "rank 4." and insert -- rank 4, --, therefor.

In Column 46, Line 14, delete "third" and insert -- third, --, therefor.

In Column 46, Line 38, delete "14-18" and insert -- 14-18, --, therefor.

In Column 47, Line 1, delete "15-18" and insert -- 15-18, --, therefor.

In Column 48, Line 41, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 48, Line 61, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 49, Line 1, delete "16:" and insert -- 16; --, therefor.

In Column 49, Line 56, delete "(e.g." and insert -- (e.g., --, therefor.

In Column 50, Line 61, delete "terminal." and insert -- terminal, --, therefor.

In Column 51, Lines 13-14, delete "Accordingly." and insert -- Accordingly, --, therefor.

In Column 51, Line 31, delete "andor" and insert -- and/or --, therefor.

In Column 52, Line 59, delete ""id est."" and insert -- "id est," --, therefor.

In Column 53, Line 43, delete "(DVD/BlueRay)." and insert -- (DVD/BluRay). --, therefor.

In the Claims

In Column 54, Line 62, in Claim 1, delete "messeges;" and insert -- messages being a NACK message; --, therefor.

In Column 55, Line 54, in Claim 7, delete "MEMO" and insert -- MIMO --, therefor.